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An investigation of the spring and summer diet of feral mink (Mustela Vison Schreber) in Riparian and coastal habitats

Rosser, A. M.

AN   INVESTIGATION

OF THE SPRING AND SUMMER DIET OF

FERAL   MINK   (MUSTELA   VISON   SCHREBER)

IN   RIPARIAN   AND   COASTAL   HABITATS

by

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A dissertation submitted in part-fulfilment
of the requirements for the degree of
Master of Science in the University of Durham
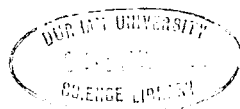
An investigation of the spring and summer diet of feral
mink (Mustela vison Schreber) in riparian and coastal habitats.

ABSTRACT

        A total of 375 mink scats were collected from
two riparian areas in Northumberland and a coastal site in
Galloway during the period from April to July in order to
investigate the composition of spring and summer feeding of
mink. In the riparian habitat, the initial order of importance
was:- fish, mammal, bird and amphibian; during the summer,
though, the mammal group doubled in importance. At Galloway,
a temporal variation in the diet was indicated, with
lagomorph increasing in importance whilst fish and crab
decreased. It was postulated that whilst the riparian diet
was largely determined by prey availability coupled to some
extent with preference for particular species, the variation
in the coastal diet may have been due to the varying
requirements of a female and kits.

        The radio-tracking of a juvenile male highlighted
the unreliability of using scats and tracks as indicators
of mink activity. The tagged animal exhibited a mainly
diurnal activity pattern with much exploratory behaviour, and
it was suggested that the former may have been the result
of maternal influence whilst the latter indicated attempts
at territory establishment or the initiation of dispersion.

        There was apparently no competition between mink and
otter in the riparian habitat, but it is a distinct possibility
in the coastal habitat and merits further investigation.

CONTENTS

DISCUSSION CONTD.

LIST OF TABLES

LIST OF FIGURES

A LIST OF ABBREVIATIONS USED IN FIGURES

Bullh	Bullhead	Crayf	Crayfish
Loach	Stone Loach	Insec	Insect
Salm	Salmonid	Amphi	Amphipod
Cypr	Cyprinid	Crab	Carcinus
Sback	Stickleback	Invrt	Invertebrate
Lampr	Lamprey	Amph	Amphibian
Blenn	Blenny	Veg	Vegetation
S eel	Sand eel	Mamm	Mammal
Cott	Cottidae		
Rockl	Rockling		
Bfish	Butterfish		
SeaSn	Sea Snail		
SeaSc	Sea Scorpion		
NRock	Non-Rockling Gadoid		
Fbone	Unidentified fish bones		
Apode	Apodemus		
Lagom	Lagomorph		
Micro	Microtis		
Cleth	Clethrionomys		
Arvic	Arvicola		
Rat	Rattus		
Ralli	Ralliformes		
Anser	Anseriformes		
Colum	Columbiformes		
Chara	Charadriiformes		
Egg	Egg-shell		
Feath	Unidentified feathers		

INTRODUCTION

The American mink, _Mustela vison_ Schreber, is
a member of the family Mustelidae and shares sub-generic
status with the European mink, _Mustela lutreola_ L. The
mink is a semi-aquatic carnivore inhabiting riparian,
lacustrine, estuarine and coastal habitats throughout the
temperate forest zones of North America. Feral populations
of _M. vison_ have become established in Northern Europe and
may have contributed to the reduction of _M. lutreola_'s range
in Finland and Russia as the two species have many features
in common, including habitat preference and diet (Novikov,
1962; Westman, 1968).

The mink has the typically long thin body of
the mustelids. The natural pelage is a dark brown, almost
black, with variable chin spots which facilitate individual
identification by means of their characteristic pattern.
Commercial breeding has exploited several mutations, however,
and coat colours now range from Pastel and Silver-Blue to
the natural colouration, dark brown and less commonly Silver-
Blue being the most frequent in feral populations (Cuthbert,
1973; Birks, pers. comm.). It is similar in size to the
polecat, _Mustela putorius_ L., males weighing 950 g and
measuring 400 mm head-body length, whilst females are
considerably smaller, 580 g and 350 mm respectively (Hewson,
1972). Despite their aquatic predilection, mink show few
adaptations pertinent to amphibious behaviour. The feet are
no more webbed than those of the wholly terrestrial polecat,
although the pelage contains a greater proportion of guard
hairs. Although aquatic vision is inferior to that on land,

Dunstone and Sinclair (1978) have shown that, if the mink limits its aquatic hunting to bright light conditions, it is at no greater disadvantage than when hunting on land in twilight. In addition, Poole and Dunstone (1976) have postulated that the observed hunting method of prior fish location from a terrestrial vantage point (Herrick, 1892) may be a behavioural means of compensating for this poor vision.

The American mink was introduced into Europe in the 1920's when a number of fur farms were established. Soon after its introduction, escapes of ranch mink occurred in many countries as a result of inadequate security. Feral populations became established in Sweden in 1928 (Gerell, 1967a), in Norway in 1930 (Wildhagen, 1956) and in Britain in 1938 (Thompson, 1968), and have been reported in Iceland (Gudmunsson, 1952), Finland (Westman, 1966) and Ireland (Deane and O'Gorman, 1969).

The first confirmed report of feral mink breeding in Britain was in 1955 (Linn and Stevenson, in press). Being an opportunist and generalist carnivore, mink spread rapidly along water courses, as dispersing juveniles and transients extended the range. In Devon, Linn and Stevenson (in press) describe a two-stage colonization in which mink were initially restricted to the Teign valley, possibly due to the lower carrying capacity of the headwaters. The second phase was an explosive dispersion during which mink migrated long distances to find favourable habitats.

Mink are associated with freshwater habitats, particularly streams and rivers where there is considerable vegetation cover (Errington, 1961; Southern, 1964). Hall (1928), Gerell (1968) and Hatler (1971) have also described

coastal populations in the United States, Canada and Sweden respectively.

In Britain, mink are similarly associated with fresh water (Thompson, 1968), although Cuthbert (1973) has reported the presence of coastal mink on the rocky shores of Lewis and Arran and on the north-east coast of Scotland near Aberdeen. Thompson (1971) also maintains that, providing food is abundant, mink may inhabit areas away from water for some time. Gerell (1970) found, however, that they are mainly confined in their activities to areas near water; but during the winter when rivers are frozen, mink may depend on rodents in areas away from water courses (Gerell, 1967a). In addition to their preference for aquatic habitats, mink also require an area which contains potential den sites (Errington, 1946; Gerell, 1967a). In North America, they frequently inhabit deserted muskrat, Odonatra zibethica, burrows, whereas in Europe eroded tree root systems and rabbit, Oryctolagus cuniculus, burrows are favoured.

REPRODUCTION

As it is an orgainism of economic importance, the reproductive physiology of the mink has been well-documented (Enders, 1952). In ranch mink, mating occurs from February to March, although from a review of the literature, Chanin (1976) concluded that the mating season of feral animals lasts from February to April with a peak in March. The female may remain receptive for three weeks after the onset of the photoperiodically-induced oestrus and during this time, mating may induce ovulation.

In addition to being induced ovulators, mink also
exhibit delayed implantation which restricts births to
a limited period following a post-implantation gestation
time of 27-33 days. The litter size of ranch mink is 3-6
kits; a similar range has been reported from feral
populations (Gerell,1971; Chanin,1976). Parturition
occurs in late April/May and the kits remain with the
mother until late August when they begin to disperse, and
finally reach sexual maturity at ten months. Enders (1952)
reports that a female may remain fecund for seven years
breeding every year, thus the potential for population
increase is vast.

TERRITORY AND ACTIVITY

Mink are solitary except during the breeding
season and tend to be territorial. The size of territory
varies according to the suitability of the habitat, but
the mean sizes found by Gerell (1970) were 2.63 km and
1.85 km of stream for an adult male and adult female
respectively. There is intrasexual conflict over territory
and a female may hold a territory against a male for some
time (Gerell,1970), particularly during pregnancy when
aggression is increased (Maclennan and Bailey,1969).
Gerell (1970) concluded that, in his study area, population
density was the main factor controlling home range size.
Chanin (1976) noted that although food availability was
relatively lower on his study area than that of Gerell's
(1970), the territory sizes were only 20% larger, and he
postulated that territory size was limited by an energetic
constraint,after which point increased food intake did

not compensate for the energy consumed in patrolling the boundaries.

Gerell (1970) found a weak correlation between home range size and the number of dens used, the average number per territory being three, whilst Schladweiler and Storm's (1969) radiotracking study recorded the use of thirteen different dens by a female and her kits. The daily movement pattern recorded by Gerell (1969) consisted of a series of oscillations in which the mink tracked back and forth in a single area before repeating the procedure in another sector of the territory. The deposition of scats and scent marks at territorial boundaries is thought to discourage intruders (Gerell,1970), but is probably more effective against resident neighbours than transient animals (Chanin 1976).

Gerell (1969) investigated the movements and activity patterns of feral mink using radiotracking techniques. A total of six animals, five males and one female were tracked for continuous periods of fourteen days. The males were mainly nocturnal at all seasons, and the activity peaks coincided with those of prey species. The single female showed a low level of activity during pregnancy and then became diurnal following parturition, during which time her activity also increased. Gerell (1969) concluded that individual activity patterns were determined by a combination of prey availability , reproductive season and environmental factors.

Hatler (1971) reported that, in a coastal area of British Columbia, mink hunted mainly at low tide and in Shetland the otter, which has similar habits, was

apparently active at all states of the tide (Watson, 1978).
The difference between the hunting activities of coastal
otters and mink can be attributed to their distinctive
hunting strategies; otters actively dive and pursue fish
whilst mink appear to hunt amongst rock pools on the
intertidal zone.

DIET

The feeding ecology of the mink has been in-
completely studied in North America, most of the work concen-
trating on the winter diet. More extensive studies have
been prompted in Europe, however, where it has been necessary
to discover the impact of feral mink on the native fauna.

Research in America (Dearborn, 1932; Hamilton, 1936,
1940, 1959; Sealander, 1943; Guilday, 1949; Errington, 1954; Wilson,
1954; Korschgen, 1958; Hatler, 1971, and Sargent, Swanson and
Doty, 1972) has generally shown that mammals formed the
greatest bulk of the diet, accounting for 32-54% of the items
consumed. Muskrat was frequently the most important species
taken, although Hamilton (1940), Guilday (1949), Wilson
(1954) and Korschgen (1958) report that small rodents were
taken more often. Fish were of secondary importance in all
the studies, except that of Wilson (1954) where they
accounted for 60% of the diet. Crayfish, Astacus astacus,
and frogs alternated in tertiary importance, superceding
birds which contributed only a minor percentage.

In Sweden, Gerell (1967b, 1968) found that the diet
of mink varied with habitat and season, the greatest
seasonal changes being in spring and autumn. The results
from nine different habitats compiled over four years showed
that fish provided the bulk of the diet, mammals were of

secondary importance, with arthropods, mainly crayfish,
third in importance, whilst birds and amphibians accounted
for the smallest proportions of the diet. Fish were
particularly important during the winter and spring when
water temperatures were low, whilst mammals and crayfish
formed the greater part of the summer and autumn diets,
and amphibians seemed to provide a buffer food source
during the change from summer to winter diet. The majority
of fish taken were small, perch and cyprinids of less than
15 cm and pike of less than 20 cm. Erlinge (1969) reported
a similar size range, but, in his area, mink appeared to
take greater numbers of smaller fish. In his study, fish
formed a larger percentage of the diet and were important
in spring, autumn and winter, whilst the summer food
consisted mainly of birds. Mammals formed a smaller
proportion of the diet than in Gerell's (1968) study,
possibly due to differences in habitat.

In Britain, Day and Linn (1972) carried out the
first mink diet study on material gathered from England
and Wales, using the technique of gut content analysis.
The order of occurrence of the major prey groups was as
follows: bird, mammal, fish and crayfish. (The importance
of fish is likely to have been underestimated by the study
technique.) There was a significant increase in fish
importance during the summer which contrasts with Swedish
results. Due to the broad nature of this study, however,
little value is gained by considering such details. The
results of Akande (1972), who analysed both scats and gut
contents from a wide area of Scotland, are more similar
to those obtained in Sweden. Fish formed the majority of
prey occurrences, birds were second in importance and

mammals third. She divided the year into warm and cold
months, May-September and October-April respectively;
during the cold months, fish were of major importance but
decreased during the summer in favour of birds; mammals
remained constant. Cuthbert (1979) collected scats from
three rivers in Scotland and a coastal region. Fish formed
the main food class, and were the most important prey at
all times of the year. Mammals were the second most
important dietary item, whilst birds contributed a smaller
percentage of the diet. Cuthbert (1979) concluded that
the overriding factor affecting mink diet is difference
in prey availablity, and that therefore regional studies
are rarely comparable.

Chanin (1976) and Wise (1978) have both carried
out detailed studies on mink feeding ecology in contrasting
habitats, in order to link diet with prey availability in
a quantitative manner. Their results were markedly different,
possibly because Chanin (1976) used frequency of occurrence
whilst Wise (1978) quoted bulk analysis data. Chanin (1976)
found the order of prey importance on the river Teign in
Devon to be fish, mammal and finally bird, whilst Wise's
(1978) results placed mammals first followed by fish and
bird. On an eutrophic lake, both authors agreed that fish
were of primary importance followed by birds and then
mammals, though the percentages calculated in the two
studies varied significantly.

In summary, the feeding data from Britain show
that, on an annual basis, fish form the major part of
the diet, the relative importance of birds and mammals
varying according to habitat. There also appears to be
some seasonal variation, but this is less marked than in

Sweden. Generalisations about the specific composition
of the diet are valueless unless the prey availability is
also considered, due to the variation between habitats.
When comparing results, the methods of analysis and
presentation of results must also be taken into account.

COMPETITION WITH THE OTTER

The decline of the otter population in Britain has
been attributed to competition with mink for prey, territory
and den sites. From an analysis of hunting records,
Chanin and Jefferies (1978) concluded that otters declined
in many areas before mink became established. Recolonisation
by otters may, however, be affected by the subsequent
establishment of mink.

Food studies in Sweden have shown that there is a
60-70% food overlap composed mainly of fish. Of the fish
taken by the otter, however, 30% exceeded the maximum size
of those taken by the mink (Erlinge, 1969). Erlinge (1969)
concluded that during the summer, the mink is less able to
pursue fast fish and hence does not compete with the otter,
but may do so during winter when general prey availability
is reduced and fish become relatively more easy to capture
due to low water temperatures. In a study of the interspecific
relations between mink and otter, Erlinge (1972a) observed
that mink did not succeed in colonising an area where the
otter population was established.

In Britain, Chanin (1976), Wise (1978) and
Cuthbert (1979) have compared the diets of sympatric mink
and otter, whilst the workers investigating the diet of
mink have compared their results with those published on
otter diet (Akande, 1972; Day and Linn,1972). Day and Linn

concluded that the mink is probably exploiting an unfilled
niche and is unlikely to compete with any British carnivore,
even the otter which takes 70-90% of its diet as fish
(Stephens, 1957). Akande (1972) concluded from her
Scottish study that the mink is unlikely to compete with
the otter due to the amount of terrestrial prey and the
size of prey which it selected. In contrast, Cuthbert (1979)
in an investigation of the diet of both otter and mink in
Scotland found no significant difference between the size
or species of fish taken. Chanin (1976) studied the diet of
otter and mink from two contrasting habitats in Devon,
Slapton Leigh, an eutrophic lake and the oligotrophic
river Teign. In both areas, the otter took 90% of the diet
as fish, a prey group which comprised only 55% of mink diet.
As both mustelids consumed a similar proportion of salmonids
and eels on the river Teign, Chanin (1976) concluded that
there is potential for competition. In contrast, the
differing proportions of fish species and the availability
of bird and mammal prey precluded competition at Slapton
Leigh. Wise's (1978) results are similar to those of
Chanin (1976), she recorded a diet overlap of 40%, of which
63% was fish, but with a greater number of large fish
consumed by the otter. At Slapton the 38% prey overlap was
composed mainly of fish (82%); there was no differential
size selection in this area.

Several authors, (Jenkins, Walker and McCowan, 1979;
Moors, 1975; King, 1971 and Lockie, 1961) have concluded that
carnivore feeding behaviour varies according to prey
availability within the study area and Erlinge (1969) and

Cuthbert (1979) assert that this is certainly so for mink.
As little has been done on the diet of feral mink in
Northumberland, it was planned to investigate the summer diet
of mink in this area, with reference to prey availability.
Although possibly contributing little to the overall
understanding of mink feeding ecology, the local knowledge
of interactions with the prey populations may prove useful
in the management of riparian habitats. In addition,
Northumberland has a relatively healthy otter population
(K.Elliott pers. comm.) in comparison with other parts of
England and Wales and hence provided an ideal opportunity
to compare the diets of mink and otter.

The occurrence of mink on the Galloway coast may
be due to a recent colonisation and it is possible that the
animal may spread throughout the coastal districts of
Scotland, which are at present inhabited by the otter, and
hence the mink may be a potential competitor.

In addition to studying the diet of feral mink,
it was planned to trap and radiotrack an individual to
determine how much time was indeed spent in an aquatic
environment and whether the animal does venture away from
the river. This was necessary because during the early parts
of the study very few scats were found and it was only
once breeding dens were located that the sample size
increased. Thus it was hoped to gain some knowledge of
mink movements and presence in the area by trapping and
tracking an individual. Knowledge of the regularity of
activity bouts and the distances travelled within a
single period may give some indications as to territoriality
and the catchment from which prey is obtainable. (The
radiotracking data are presented in the Appendix 1).

STUDY AREAS

Scats were collected regularly from two main
study areas, and a third was sampled on a single occasion.
The main study was based on a comparison of mink diet from
two sites on the river North Tyne, Chollerford and the
Chirdon Burn, with that from two sites on the Galloway
coast, a wooded area and the Ross Peninsula. During the
initial stages of the study, stretches of the rivers
Wansbeck, Font, Blyth, Tees and Greta were also surveyed
for signs of mink presence (Fig 1). A small sample of scats
was collected on the river Greta, a tributary of the river
Tees, and on the Tees at Piercebridge. The Greta is a
swift-flowing oligotrophic stream very similar to the
Chirdon Burn, whilst the Tees has features in common with
the North Tyne, hence only the main sites will be described.

CHOLLERFORD

The study area extended from one kilometre
upstream of Chollerford Bridge (Nat. Grid Ref. NY 905693)
to the confluence of the North and South Tyne near Hexham
(Nat. Grid Ref. NY 917661), a total of 3.5 km. The whole
area was searched at least once on both banks during the
course of the study, but as signs of mink were few, the
major survey was concentrated on a short stretch of 500 m
from Nat. Grid Ref. NY 907691 to Nat. Grid Ref. NY 917683,
which appeared to have the highest mink population.

The North Tyne rises in the Kielder Forest and
flows south-east to its confluence with the South Tyne at
Hexham. It is an oligotrophic river flowing through an area

FIG 2   A MAP OF THE CHOLLERFORD STUDY AREA SHOWING THE
PRINCIPAL HABITAT TYPES

Chollerford

Dunkirk

Humshaugh
Mill

Roman
Bridge

— 570

KEY

1   Pasture and trees
2   Cliffs and beech
3   Trees and scrub
4   Open fields
5   Parkland
6   Sand and scrub
7   Conifer plantation
8   Private land
        Public footpath
        Tributary

Scale 1:10,560

Walwick
Grange
Farm

Wall Mill

0   500   1000 yards

Nether
Warden

— 597

391   392

Warden
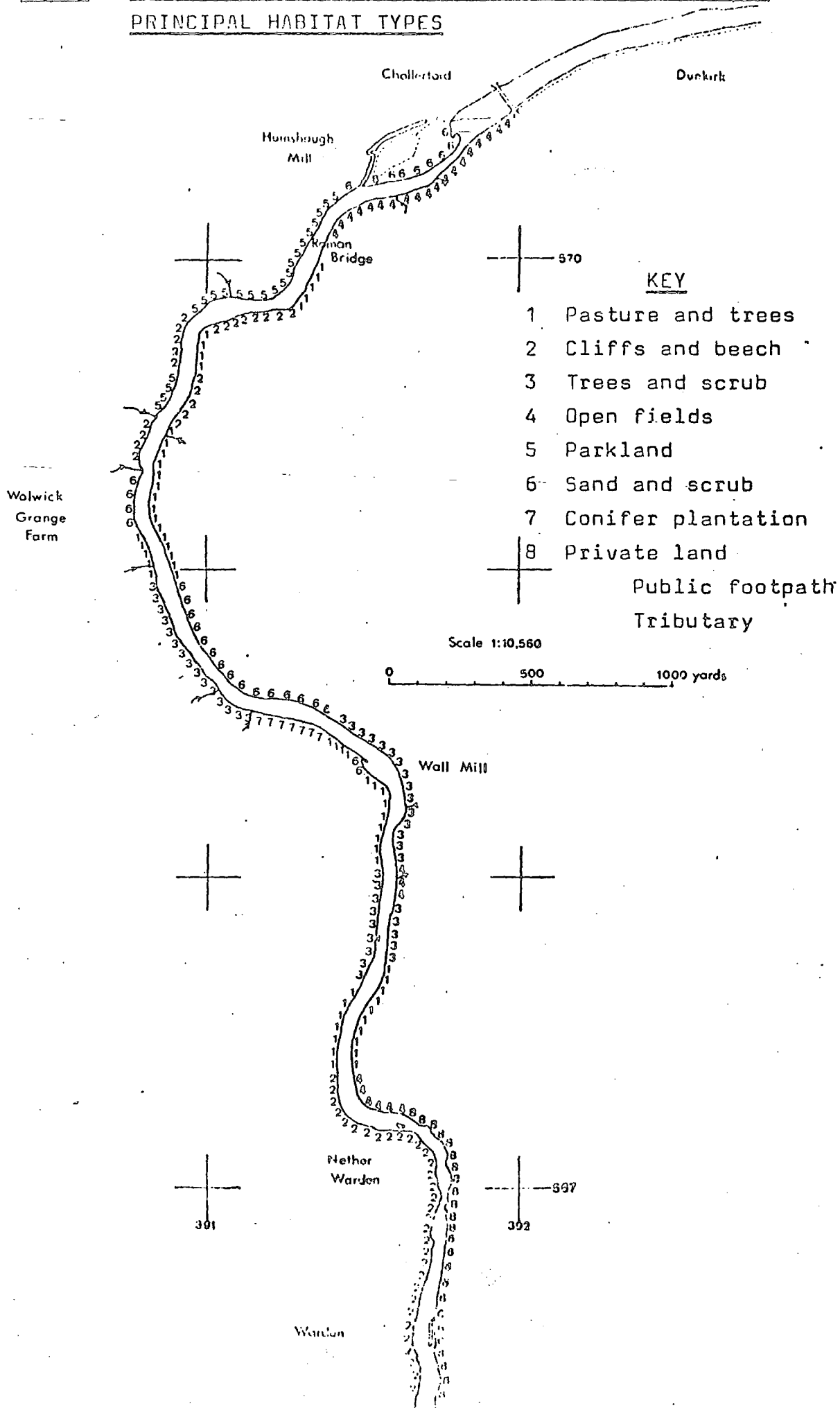
of limestone with an average width of 15 m and a maximum
depth of 3 m in parts of the study area, although this
varies with the waterflow characteristics. The surrounding
land is agricultural, being mainly pasture interspersed
with small copses. Within the study area there are several
different habitat types, as can be seen from the map, Fig 2.

GEORGE HOTEL AREA

In this area the river is 20 m wide and flows
slowly. The river is bounded by steep banks rising at an
angle of 60 degrees to three metres above mean water level.
Mature sycamore, Acer pseudoplatanus, and alder, Acer
glutinosa, trees grow at the water's edge and overhang the
river forming a dense canopy to the banks. At low water
levels a muddy track is exposed running parallel to the
river 0.3 m from the water's edge. The undergrowth consists
mainly of grasses and is sparse due to the shading effect
of the tree canopy. A public footpath runs along the top of
the bank, 5 m from the water, separating the river from a
background of arable and rough pasture land.

THE ISLAND

Below the bridge at Chollerford is a sandy area
of approximately 0.3 ha, known as the "Island", separating
the old mill from the river. The area is dissected by
water runnels and depressions which temporarily fill during
floods forming small pools in which fish become trapped.
The dominant trees are ash, Fraxinus excelsior, and sycamore
with a dense shrub layer of willow, Salix spp., and alder,
and a ground flora comprising Petasites hybridus, Lysmachia

vulgaris, Centaurea nigra, Rubus fruiticosus, Crepis mollis, and Phragmites australis. From the Island down to the junction with the South Tyne, several different habitat types alternate:-

Parkland:

Areas of open short grass (less than 5 cm high) reaching to the water's edge scattered with occasional beech, Fagus sylvatica, and oak, Quercus spp. Cover is virtually non-existent apart from an occasional alder at the foot of the bank.

Open fields:

Similar to the above parkland, but used as rough grazing (grass 30 cm high) with a complete absence of trees; the only refuge is afforded by boulders or rabbit burrows.

Pasture with Trees:

Open fields of rough pasture with banks of gentle gradient bounded by a line of trees at the water's edge. Alder and sycamore are found at the foot of the bank with beech and oak several metres further from the water. In this habitat, soil is eroded from many of the tree roots forming a complex network of potential dens.

Sand and Scrub:

The banks are predominately sand, often forming flat sandy beaches, or may be boulder-strewn. The vegetation is very dense forming a low ground cover to a height of 1.5 m. The dominant species are willow and alder scrub with incidental sycamore and ash further from the water's edge. Stands of grasses, Phragmites, Crepis, Centaurea, and Lysmachia, add to the undergrowth in this habitat.

Trees and Scrub:

Boulders, willow and Phragmites at the water's
edge leading to a tree layer bounding pasture. Similar to
the pasture and tree habitat, but with a very different,
more densely-covered waterline.

Cliffs with Beech:

There are several areas where the river cuts
through a hard limestone, forming near-vertical cliffs.
There is a heavy tree cover of mixed deciduous woodland species
with a sparse herb/shrub layer, both surmounting the cliff
and at its foot. In addition to the vegetation, den sites are
afforded by piles of boulders, crevices and caves in the rock.

CHIRDON BURN

The Burn rises in the Wark Forest and flows in a
north-easterly direction through coniferous forestry
plantations out onto the exposed Chirdon Common. Just prior
to its confluence with the North Tyne, the stream becomes
wooded with fairly dense cover.

It is an oligotrophic burn 7-10 m wide with an
average depth of 1 m and a maximum depth of 1.3 m when not
in spate. The bed is covered with large boulders giving
a turbulent flow pattern. The sandy banks are steep but only
3 m high, covered with a mixed woodland/waterside scrub
vegetation of alder, ash, willow, oak, bramble, ferns and
grasses.

Upstream of the Chirdon Burn, the banks of the
North Tyne are covered with a dense scrub layer of alder,
sycamore, willow, bramble and Phragmites. At Bent House
Bridge, the bank type changes dramatically to a

FIG 3a   RIVER FLOW FOR THE RIVER NORTH TYNE AT REAVERHILL STATION

----- Maximum daily flow rate
-----. Minimum daily flow rate
——— Monthly mean flow rate
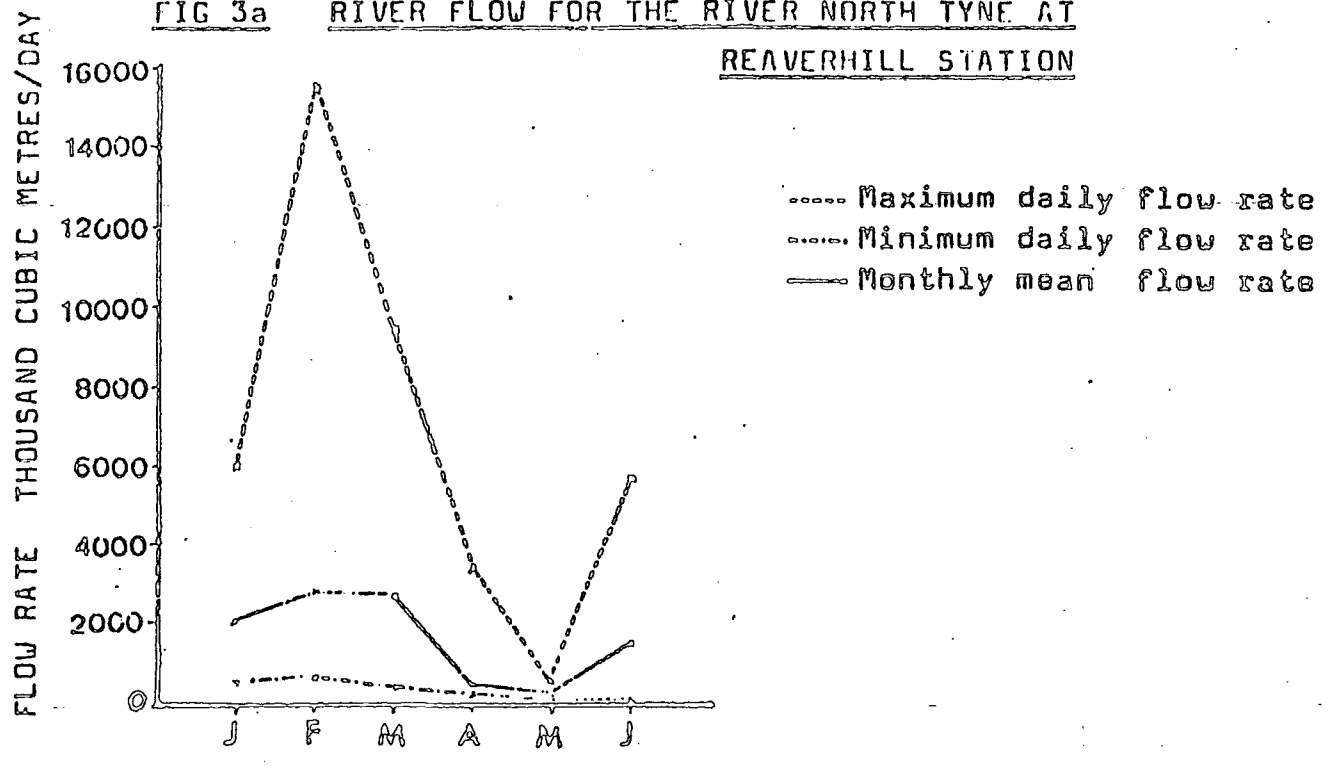
FIG 3b   RIVER FLOW FOR TARSET BURN

----Maximum daily flow rate
-----Minimum daily flow rate
———Monthly mean flow rate
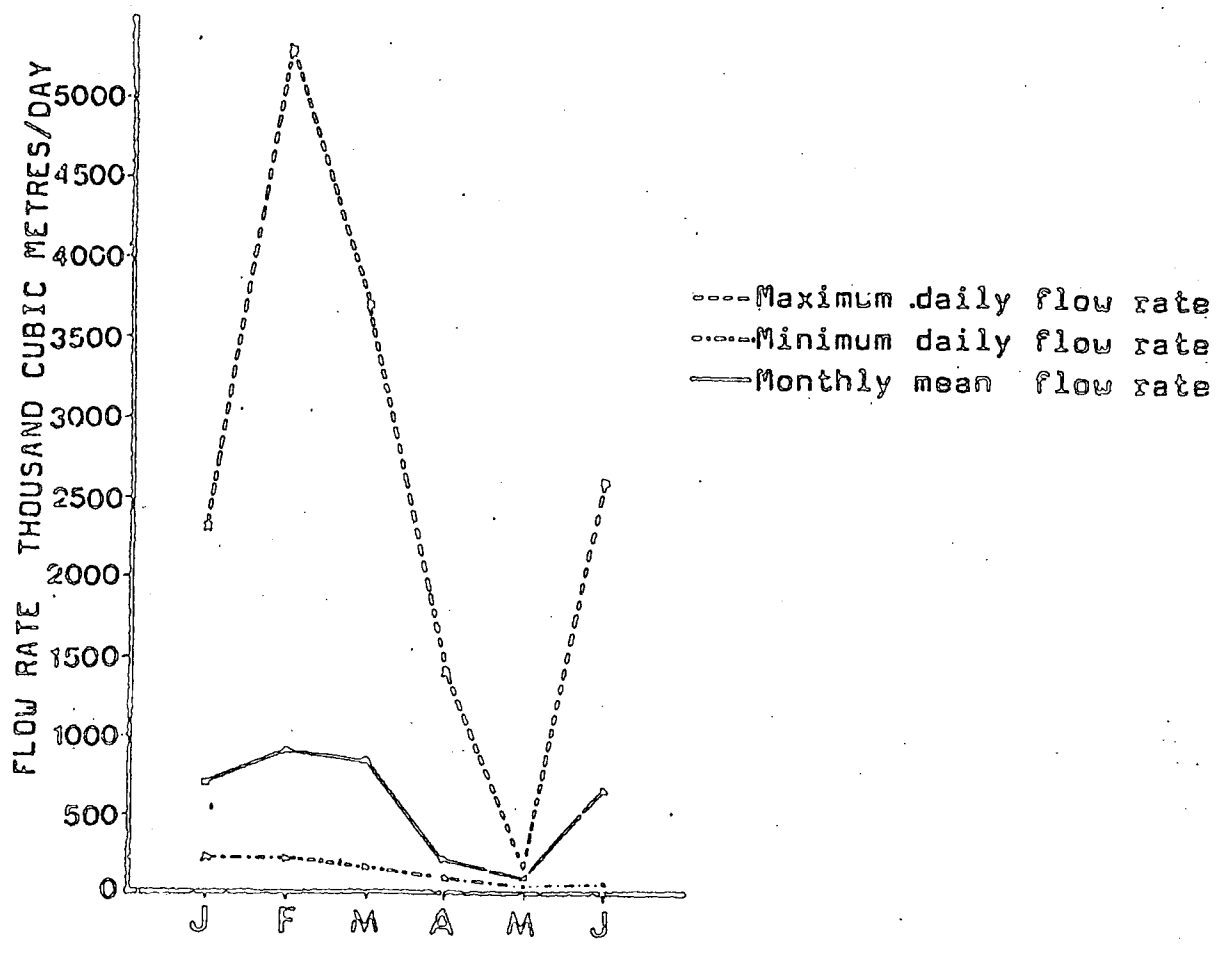
preponderance of herb species, Umbelliferae, Compositae and Leguminae. Phragmites and grasses with small willow shrubs are also present. At this point, the North Tyne is 20 m wide and flows smoothly.

The Chirdon site is at no point more than 200 m from the road and anglers take advantage of the easy access. On almost each occasion that the river was visited, anglers were present.

River Flow:

River flow data for two areas on the North Tyne were obtained from the Northumbrian Water Authority for the months January to June 1980 inclusive. Figure 3a shows the data from Reaverhill Station on the main river. The high maximum daily flow rate in February was followed by a decrease in April and May, partly due to the end of the winter thaw, but also correlating with abnormally dry weather conditions for that time of year. June and July 1980 were the wettest months on record during the summer for some years and this is reflected in the much higher maximum daily flow rate for June compared with that of the preceding month.

Figure 3b shows data for Tarset Burn, a tributary of the North Tyne joining the main river at the same location as the Chirdon Burn, but from the opposite direction. The pattern is very like that from Reaverhill Station, and shows that conditions were similar throughout the region, although of course gross flow in the tributary is much less than that recorded on the main river.

FIG 4   CONTRASTING AREAS OF THE RIVER NORTH TYNE

Fig 4a: Looking downstream from the profusion of vegetation
in the foreground on the Island to the Roman Bridge.

Fig 4b: An area of rapids and turbulent flow downstream of
the Mill, showing the contrast in amount of cover on
the two banks.

Fig 4c: A typical stretch of the Chirdon Burn.

Fig 4d: The breeding den on the Chirdon Burn was situated
amongst the roots of the sycamore tree in the
centre of the photograph, at the Burn mouth.

Ross Bay

Scale 1:25,000

0   500   1000

KEY

Slack
Heugh

Little
Ross

545

543

263   267

22
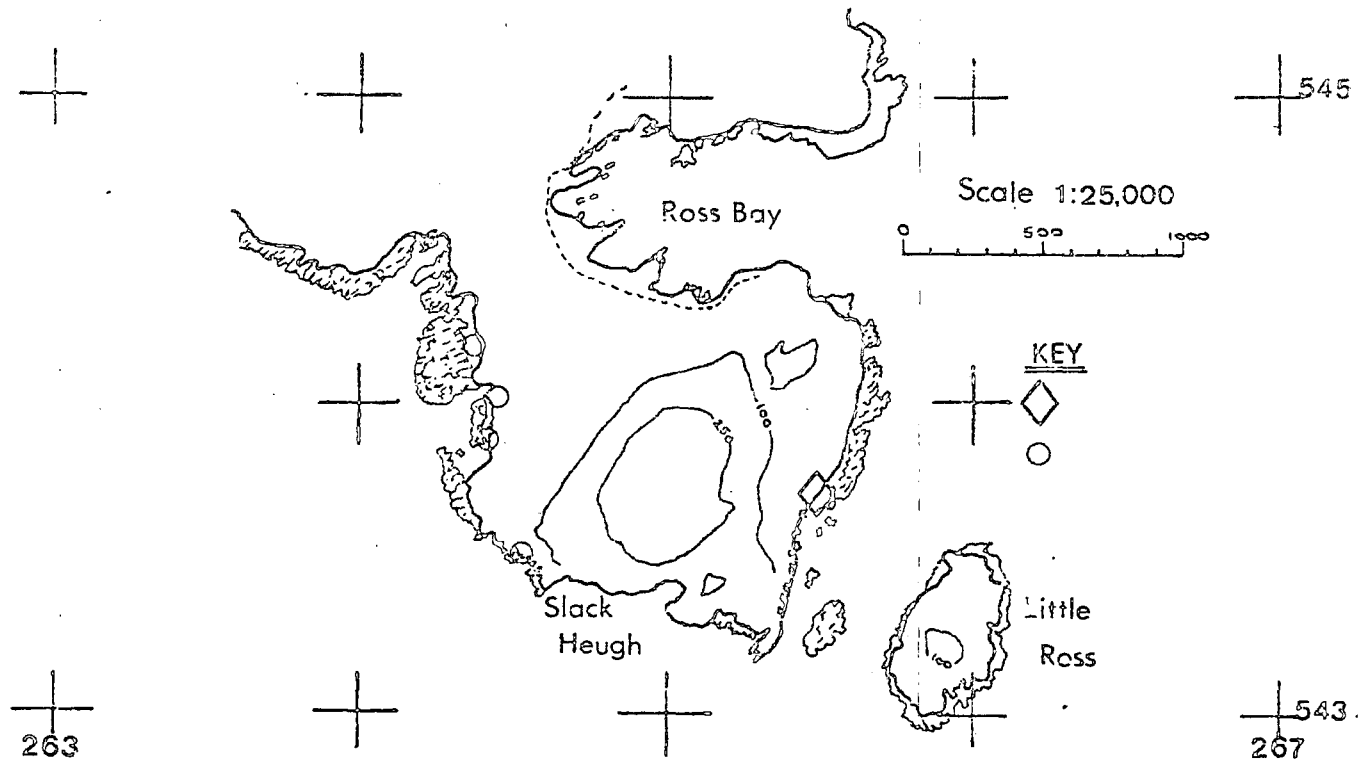
GALLOWAY

Two sites were chosen on the west coast of the
Dee estuary in Kirkudbright (Fig_5_). The first area consisted
of 1 km of wooded coastline, below hich at low tide
approximately 10 m of rocks and seaweed were exposed, with
numerous small rock pools. The main vegetational species
which formed a continuous dense cover 1 m from the mean
high tide level were :- ash, alder, sycamore, bramble,
dog-rose, Rosa canina agg., sea thrift, Armeria maritima,
sea plantain, Plantago maritima, and sea mayweed, Matricaria
maritima, backed by a mixed deciduous wood of sweet chestnut,
Castanea sativa, ash and oak with little ground cover, apart
from occasional clumps of brambles and ferns. Jumbled piles
of rocks and eroded tree roots provide a relatively small
number of den sites, in contrast to the riparian areas.

ROSS PENINSULA

The second area, the Ross Peninsula, is a desolate
area of exposed coastline at the edge of a steep hillside
rising to 76 m. The centre of the peninsula consists of a
mixture of arable, rough pasture, and forestry land. On the
south-east side, above the mean high water mark, there is
a 10 m strip of boulders devoid even of lichens. Above this
is an area of rough ground consisting of boulders, scrub
vegetation, grasses, sea thrift, sea plantain, sea campion,
Silene maritima, stonecrop, Sedum spp., and bramble.
Interspersed along the rough ground are thickets of gorse,
Ilex spp., and hawthorn, Crategus monogyna. At low tide,
rock pools cover a substantial portion of the intertidal
zone, approximately one quarter of the total surface area

FIG 5   CONTRASTING AREAS OF THE COASTAL SITE

Fig 5a: Little Ross, taken from the breeding den, showing
          the typical rocky coastline in the foreground. The
          vegetation and cover on Little Ross are similar to
          that of the mainland.

Fig 5b: The breeding den at Galloway. Fragments of scat
          containing crab carapace are visible amongst the
          grass in the foreground.

being underwater. Seaweeds, _Fucus serratus_ and _F. vesiculosus_,
did not form an extensive rock cover, but were present in
rock pools.

At the tip of the headland, there is no access to
the south-west side at sea level due to the steep cliffs.
On the south-west, the character of the coast changes again
from vertically tilted strata with large intervening rock
pools at Slack Heugh, to a wide boulder-strewn, gently-
shelving storm beach about 100 m wide, known as the Bents.
The beach is separated from the low-lying fields by a short
strip of marshy land. The flat boulder area has fewer rock
pools than on the south-east side, and the majority of these
are on the spits of rock which dissect the beach. The
seaweed cover is much more extensive than on the south-east,
possibly because the gentle gradient and numerous rocks
provide more opportunity for attachment, despite the higher
degree of exposure on this side.

On both sides of the peninsula, the large boulders
and rocky crevices provide a number of potential den sites.
There is, however, very little vegetation cover on the south-
west.

Prey Availability:

It had been planned to census prey populations to
gain an estimate of prey availability in the study area. Due
to the limited time available, however, it was only possible
to make observations on the presence and/or absence of the
main prey species. Mammals were recorded by Longworth
trapping and identification of tracks on the North Tyne;
visual counts of lagomorphs at dusk were also attempted.

The different bird species seen during visits
to the study areas were recorded and additional information
was supplied by P.R. Evans (pers. comm.).

The species distribution of river fish on the
North Tyne and Tees was made available by the Northumbrian
Water Authority from electrofishing data and records of
anglers' catches.

A rock pool survey was carried out at Galloway at
low tide on two occasions, but remarkably few fish were
found.

Two trap-lines were set in differing habitat
types at Chollerford on the North Tyne, giving a total of
54 trap-nights. The first site was along the edge of a
cereal field at the top of a 10 m high steep bank 100 m from
the river, and the second site was 20 m from the river at
the foot of a bank in a mixed deciduous and coniferous
plantation, where there was little undergrowth.

The traps were set at 5 m intervals, baited with
wheat and provided with nest material. Fourteen traps were
set on two consecutive nights at Site 1 and during a total
of 28 trap-nights, two bank voles, Clethrionomys glareolus,
three field mice, Apodemus sylvaticus, and one shrew,
Sorex araneus, were caught. At Site 2, thirteen traps were
set on the same two nights in August as at Site 1. A total
of five bank voles, four field mice (two in one trap), and
one shrew were caught during the 26 trap-nights. In addition,
whilst trapping for mink in June, a water vole, Arvicola
terrestris, was caught in the same mink-trap on two
consecutive nights.

Water vole and small rodent tracks were numerous
at the water's edge. Red squirrels, Sciurus vulgaris, were

seen on several occasions. Few rabbits were seen in the
study area on the west bank of the North Tyne, but a warren
showing signs of use was located. On the opposite bank, a
number of juvenile rabbits were seen from early April
(S. Pickering, pers. comm.) to late August. There was no
direct evidence of common rats, Rattus norvegicus, but due
to the proximity of several farms, it is likely that these
are available to mink.

The following bird species were seen on the
North Tyne :-

Goosander	Mergus merganser
Mallard	Anas platyrhyncos
Little Grebe	Podiceps ruficollis
Moorhen	Gallinula chloropus
Kingfisher	Alcedo attlis
Pied Wagtail	Motacilla alba yarrellii
Grey Wagtail	Motacilla cinerea
Dipper	Cinclus cinclus
Heron	Ardea cinerea
Lapwing	Vanellus vanellus
Sandpiper	Tringa hypoleucos
Curlew	Numenius arquata
Redshank	Tringa totamus
Greenshank	Tringa nebularia
Oystercatcher	Haematopus ostralegus
Pheasant	Phasanius colchicus
Partridge	Perdix perdix
Pigeon	Columba palumbus
Rook	Corvus frugilegus

Woodland birds

According to the electrofishing data, the following species are present in the North Tyne :-

Trout	Salmo trutta
Salmon	Salmo salar
Stone Loach	Nomacheilus barbatulus
Three-spined Stickleback	Gasterosteus aculeatus
Eel	Anguilla anguilla
Brook Lamprey	Lampreta planeri
Cyprinids	Cyprinidae
Bullhead	Cottus gobio

Trout were the most frequent species, followed by eels.

No adult amphibians were encountered on the North Tyne, but in early summer, concentrations of tadpoles, Rana temporaria, were found basking in the shallows.

It seems likely that the mammalian and bird species on the Tees were similar to those on the Tyne, with the possible exception of some of the waders, Charadriiformes.

The fish availability must also have been similar, although migratory fish are likely to be less numerous as few can penetrate the pollution of the Tees estuary. The main cyprinids are :-

Chubb	Leuciscus cephalus
Roach	Rutilus rutilus
Perch	Percha fluviatilis

On the coast, a rabbit census was carried out along a 500 m transect at dusk. Only eleven individuals were encountered. Brown hares, Lepus capensis, were also present as evidenced from skeletal remains and several sightings. No other mammals were encountered during the brief visits.

The sheer cliffs of the Ross Peninsula support

a sea-bird colony and the following species were recorded:-

Cormorant	Phalacrocorax carbo
Shag	Phalacrocorax aristotelis
Kittiwake	Rissa tridactyla
Herring Gull	Larus argentatus
Greater Black-backed Gull	Larus marinus
Oystercatcher	Haematopus ostralegus
Curlew	Numenius arquata
Sandpiper	Tringa hypoleucos
Knot	Calidris canutus
Redshank	Tringa totamus
Rock Dove	Columba livia
Rock Pipit	Anthus spinoletta

Woodland birds

Blennies, Blennius pholis, butterfish, Pholis gunnellus, and rockling, Gaidropsarus vulgaris, were the only fish species found in the rock pools. In addition, the shore crab, Carcinus maenas, and edible crab, Cancer pagurus, were also found.

METHODS

SCAT COLLECTION

River banks were surveyed for the following signs of mink presence: tracks, scats and prey remains, the locations of which were marked as accurately as possible on 1:2500 maps.

Mink scats have an unpleasant odour when fresh, and are normally firm and tubular and may have a distinctive twist if containing fur or feather remains. In instances where the identity of a scat was uncertain, the scat was collected but excluded from the analysis. Where possible, the whole river bank area was searched, with particular attention being paid to characteristic sites for scat deposition, such as stones in mid-stream or by the water's edge, at den entrances, under bridges, on logs and occasionally on piles of grass (Gerell, 1968).

It was originally planned to visit each study area at fortnightly intervals in order to investigate the relative importance of prey species in the diet throughout the study period. Difficulty was experienced, however, in finding scats, due to the unusual weather patterns producing spate conditions which removed any mink signs, hence the interval between samples became longer and less regular.

TREATMENT OF SCATS

On collection, the scats were labelled with date, area, estimated age and site of deposition. The whole scat was removed intact wherever possible. Some authors

(Stephens, 1957; Wise, 1978) have pointed out that this
procedure may affect the animals' behaviour. It was felt,
however, that sufficient odour would remain in the ground.
The scats were dried at 50° C for 24 hours and weighed to
the nearest 0.01 g. Initially, a sample of ten scats was
dried for a further 24 hours. As there was no significant
difference in weights after 24 or 48 hours, the former
was deemed to be a sufficient drying period to obtain
a reliable measure of dry weight. Several authors have
advocated crumbling the dry scat (Erlinge, 1968a; Gerell,
1968; Chanin, 1976; Wise, 1978), but it was felt that
this procedure might damage fish vertebrae, hence the scats
were soaked overnight in a 1% detergent solution to break
down the binding mucous. "Steradent" and sodium hypochlorite
solution have also been used (Stephens, 1957; Webb, 1975;
Cuthbert, 1979), but it was thought that detergent had the
advantage of being less corrosive. The remains were washed
through a coarse 10 sieve followed by a 60 sieve. The
washed remains were spread in petrie dishes and dried at
50° C prior to analysis. A binocular dissecting microscope
was used when separating out the undigested fragments.
Hair and feathers were examined under a microscope.

IDENTIFICATION OF PREY REMAINS

Mammalian prey was identified by hair characters,
after Day (1966), and in some cases teeth and jaw bones
were also diagnostic (Lawrence and Brown, 1967). The methods
adopted of examining cuticular scale pattern and medullary
configuration, by making gelatine casts and mounting in
70% alcohol were as described in Day (1966). To obtain

cross-sections, Mathiak's (1938a) method was used. A hair
was embedded in ethyl acetate on a thin strip of balsa
wood. When the substance was completely dry, sections of
approximately 0.5 mm were cut with a razor blade. A
reference collection of mammalian hair and teeth was
obtained from the Hancock Museum and Sunderland Museum.

Birds were identified from feather remains ,
using Day's (1966) key, in conjunction with a reference
collection. In several cases, however, the characteristic
barbules of covert feathers were not available, making
identification impossible. This was particularly so in
juvenile birds which were likely to have been prevalent
at the time of the study. One instance of egg-shell was
confirmed by comparison with domestic hen egg-shell. As
has been noted by Wise (1978), specific identification of
egg-shell is normally impossible as the pigment is removed
by the digestive juices.

Amphibians were identified by comparison with
a set of reference bones.

Vertebrae, jaw and scale characteristics were
used for identification of fish prey; otoliths were only
found infrequently. The keys of Webb (1975) and Wise (1978)
were followed for freshwater fish, and that of Watson (1978)
for coastal fish. As vertebrae vary in character from the
cranial to the caudal ends of the vertebral column, a
reference collection was made to supplement these keys.
The following fish were obtained:- trout, chubb, roach, dace,
perch, eel, stickleback, bullhead and grayling. Specimens
of butterfish, rockling and blenny were collected from the
coast. Prior to removing the flesh from these fish, the

fork length was measured to the nearest centimetre. To obtain the vertebral column, the fish were boiled in water to facilitate dissection of the flesh, and the hard parts were soaked in a weak solution of sodium hydroxide in order to clean the bones.

Crustacea, particularly Decapoda, were identified by the characteristic pore pattern on the carapace (Watson 1978). Shore crabs, Carcinus maenas, edible crabs, Cancer pagurus, and velvet swimming crabs, Portunus puber, were collected from the shore.

Hitherto, lampreys have not been identified from mink scats and, as brook lampreys were known to be common in the North Tyne, a feeding experiment was conducted to determine whether digestion of lamprey leaves any undigested parts which may be characteristic. Three captive mink were starved for 24 hours prior to the feeding trial to ensure that the guts had been completely evacuated. Sibbald, Sinclair, Evans and Smith (1962) found that dyed food, irrespective of composition, passed through the digestive system of the mink in three hours. Each mink received three lampreys. The scats and uneaten lamprey remains were collected the following morning and analysed. In two cases, parts of the oral sucker and the eye lenses were found. Whilst none of the lampreys had been ingested completely, no single portion of the body was consistently rejected. As a result of this feeding trial, one occurrence of lamprey in a scat from the North Tyne was identified by parts of the oral sucker.

ESTIMATION OF FISH LENGTHS

All the vertebrae of salmonids, cyprinids, eels
and stone loach, excepting those from the extreme ends of
the vertebral column (as described by Wise, 1978), were
measured to the nearest 0.1 mm using Vernier calipers.
There was some inaccuracy due to compression of the vertebra
by the calipers. It was assumed, however, that this error
would be constant for all vertebrae. Using centrum length,
the parameters of mean, maximum and minimum fork lengths
of the fish were calculated from a regression of fork length
against centrum length (Wise, 1980). In cases where there
was no overlap between the maximum length calculated from
one vertebra and the minimum length from another, it was
assumed that two fish of different sizes had been consumed
and the mean length of each was calculated. Where vertebral
length indicated that only one fish had been eaten, the
mean centrum length of all vertebrae was used to calculate
mean fork length.

An alternative method of estimating fork length
is to age fish from the annual ring pattern of scales
posterior to the dorsal fin and near the lateral line.
Knowing the age/size distribution of the population it
is then possible to back-calculate the fish length. In
this study, very few undamaged scales were encountered and
the accuracy of the method would have been decreased as the
position of the scales cannot be ascertained accurately.

PRESENTATION OF RESULTS

There has been some controversy over which is
the most efficacious method for analysing the results of

dietary studies. When considering the advantages and disadvantages of each method, it is vital to define the objectives of the analysis. For a study in which a comparison of the relative importance of items is required, an error engendered by the method will be acceptable so long as the error is consistent throughout. When absolute importance is required, however, the error must be minimised.

The three possible methods of analysis are:

1. Percentage frequency of
    occurrence.

2. Percentage relative
    estimated bulk: a volumetric estimate of each
                         item as a proportion of the
                         total scat.

3. Dry weight of remains: based on the relative
                          proportional weight of remains.

Conversion factors can be applied to any of the above three methods to correct for the differing proportions of hard parts to soft parts in the prey.

Frequency of occurrence may be calculated as a percentage of the total number of scats or as a percentage of the total number of prey occurrences:

i) $\dfrac{\text{Frequency of prey A}}{\text{Total number of scats}}$ X 100

ii) $\dfrac{\text{Frequency of prey A}}{\text{Total frequency of all prey, A+B+C}}$ X 100

The second method is preferable as the values total 100% which facilitates comparison with other sets of data. The main criticism of the frequency of occurrence method is that it underestimates the importance of small items which occur several times in a single scat, and also

underestimates large items of which no hard parts are ingested as only the flesh is consumed. In addition, it can also be argued that a single-occurrence of a small prey item may be overestimated in importance as it would be scored on an equal basis to an item which in terms of proportion of the scat was more important.

The relative estimated bulk method was proposed by Lockie (1959) and involved washing the scat and estimating the volume occupied by the remains of each prey item in order to obtain a proportional value for the importance of each item. Wise (1978) modified this method by estimating the importance of the identified prey items on an arbitrary scale from one to ten, calculating the percentage of the scat that each item accounted for and multiplying this percentage by the dry weight of the scat to produce a "bulk estimate".

In addition to the time-consuming nature of analysis by bulk estimate, the method assumes that all prey remains have a constant weight relationship to one another. This could be misleading; for example, the comparison of two scats both containing 50% lagomorph and 50% fish in which the lagomorph remains of one scat are entirely fur whilst the lagomorph remains of the second consist mainly of bone. In this case, the second scat would be relatively heavier than the first and therefore,although the proportions of both prey types in each scat are similar,the weight of fish in the second scat is taken to be greater than in reality. This type of error, although acceptable for comparative purposes, would bias estimates of absolute importance and cannot be corrected for by the application of conversion factors.

A further criticism of bulk analysis is that it
is based on a subjective estimate of relative importance or
volume (Gerell, 1968). Although Wise (1978) shows that any
worker error inherent in the estimation of importance is
constant, the problem still arises as to how to rank bone
in comparison with fur and/or feathers. Wise (1978) does
not state on which criteria her "importance" estimations
are based. Fur and/or feathers being less compact than bone,
may appear qualitatively to constitute a large proportion
of the scat whilst estimation on the basis of, for example,
weight shows that this is not the case. The discrepancy
arising from the assumption that fur and feathers have the
same weight as bone is corrected for by use of conversion
factors, but the estimate of importance cannot be corrected.
A further criticism of Wise's (1978) work, which she
acknowledges, is that items constituting less than 10% of
the scat are overestimated on a scoring system of one to ten.

An additional source of error may arise using Wise's
(1978) method as she only estimates the importance of
identifiable remains; this assumes that the prey items in the
unidentified remains are in constant proportions to those in
the identified remains. This can be seen with reference to
an hypothetical example in which only 50% of one scat is
identifiable, of which half is lagomorph and half fish. These
both obtain importance scores of 5 and, when multiplied by
the total scat weight, the relative estimated bulk for each
will be 50% of the scat weight, though in reality, the
remaining 50% of unidentified remains may not be equally
proportioned between the two prey items. This is often the
case when mammal and fish remains are present in a single

scat, as the majority of mammal remains consist of hair
which is easily identifiable whilst, of the fish remains,
only the vertebrae are identifiable. In such a case, the
relative importance of mammal would be overestimated at the
expense of fish. Application of conversion factors would
then increase the error.

The third method of analysis involves cleaning,
weighing the scat and estimating the percentage volume of
each constituent of the scat. This is obviously the most
accurate method, but is extremely time-consuming and relies
upon collection of the whole scat intact.

Comparing all three methods, Lockie (1959)
maintained that a method of analysis which provided a
constant error was a necessity and, from feeding studies
on red fox, he concluded that both frequency of occurrence
and estimated bulk gave inconsistent results; therefore he
favoured the weight of undigested remains method. Gerell (1968)
criticised this method on the grounds of its subjectivity and
time-consuming nature.

Scott (1941) and Erlinge (1967a) concluded from
feeding trials, on red fox and otter respectively, that
frequency of occurrence, despite its shortcomings, is the
only realistic method for estimating the relative importance
of prey items. From feeding trials on mink, Wise (1978)
concludes that the bulk estimate is superior to frequency
of occurrence in its consistency and superior to the weight
of undigested remains in its ease of execution.

Hewson (pers. comm.) advocates that only items
constituting over 50% of a scat be scored in frequency
analysis. Although applicable to his work comparing the

extent of fox predation on sheep in different areas, this method would give a somewhat biassed view in a study attempting to describe the seasonal feeding ecology of a predator. In the present study, many scats would have been completely ignored as no single prey item would have provided 50% of the scat; this would tend to give a false impression of the diversity of prey taken. Hewson's method does, however, have the advantage of preventing the overestimation of the importance of small prey items.

In the present study, scats were analysed by two methods, frequency of occurrence as a percentage of total occurrence, and bulk analysis. For the frequency of occurrence estimate, items were scored for presence or absence rather than frequency of the item within a single scat, which would have been less accurate. The bulk analysis was similar to that of Wise (1978), but with some modifications. The importance of the identified prey items was estimated as a percentage volume of the whole scat and multiplied by the scat dry weight. In this case, the unidentified proportions of the scat are effectively ignored, which may lead to a systematic underestimation of some items. Conversion factors calculated by Wise (1978) were applied to the bulk estimates obtained for the river data. Appendix 2 shows the methods used in the calculation of a conversion factor for C. maenas.

TABLE 1   RESULTS OF SCAT COLLECTION

AREA	NUMBER OF SCATS	TOTAL PREY ITEMS	NUMBER OF PREY/SCAT ± STANDARD ERROR	SCAT DRY WEIGHT ± STANDARD ERROR
RIVER NORTH TYNE	99	142	1·49 ± 0·10	1·28 ± 0·22
Chirdon Burn	70	108	1·59 ± 0·84	0·95 ± 0·19
Chollerford	10	13	1·44 ± 1·04	0·83 ± 0·37
George Hotel	19	19	1·00 ± 0·85	0·35 ± 0·11
RIVER TEES	11	21	2·00 ± 0·41	2·19 ± 1·02
TOTAL RIPARIAN	110	163	1·55 ± 0·10	0·81 ± 0·13
SPRING	53	77	1·30 ± 0·21	0·49 ± 0·08
SUMMER	58	86	1·60 ± 0·19	1·12 ± 0·19
GALLOWAY				
Week 14	129	335	2·57 ± 0·09	0·83 ± 0·05
Week 16	102	183	1·79 ± 0·11	0·72 ± 0·20
Week 18	33	45	1·40 ± 0·09	0·94 ± 0·10
TOTAL COASTAL	265	565	2·14 ± 0·07	1·91 ± 0·12

RESULTS

The total number of scats and date of collection from each sampling site are shown in Table 1. As only a small number of samples was collected from the three sites on the North Tyne (Chollerford, the George Hotel Area and the Chirdon Burn), the data have been amalgamated in subsequent analyses.

Very little indication of mink presence was found on the North Tyne at Chollerford during the early stages of the study, thus necessitating widening of the study area to include the Chirdon Burn. In May, a possible breeding den was located on the Chirdon Burn in the root system of a sycamore tree close to the point where the burn joins the North Tyne. On the main river at this site, scats were also found in a drainpipe 15 cm in diameter and 80 cm above ground level, and also scattered along runways overhung by vegetation. On each visit to this site, numerous tracks were found and, on one occasion, these were followed continuously for 1 km as far as Bent House Bridge.

At the coastal sites, the majority of scats on the wooded coastline were found on exposed rocks or in crevices. On the Ross Peninsula, a second breeding den was located, as was confirmed by a sighting of the kits (H. Watson, pers. comm.). Other scats were found under boulders and in sheltered positions, mainly on the south-west coast.

It is apparent from Fig 6a that the majority of scats was collected from dens and in particular from breeding dens during the post-parturition period. Most of the scats

FIG 6a   PERCENTAGE FREQUENCY OF HABITAT TYPE IN WHICH
                                              SCATS WERE FOUND
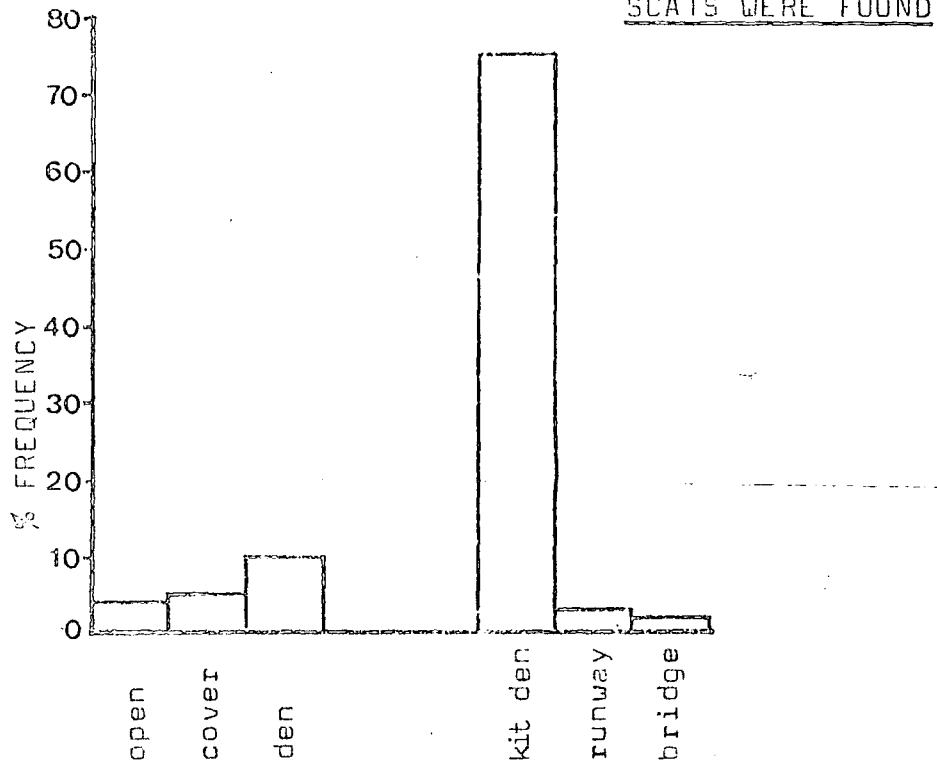
FIG 6b   PERCENTAGE FREQUENCY OF SCATTING PLACE
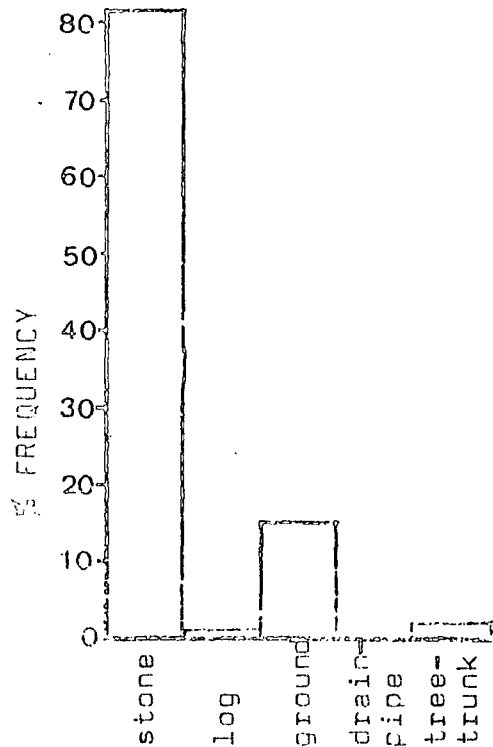
TABLE 2a: Comparison of the number of prey items comprising all scats collected (after Wise, 1978)

AREA	Chirdon Burn	Chollerford	George Hotel	River Tyne	River Tees	Riparian	Coastal
No. prey	108	13	19	142	21	163	565
No. scats	70	10	19	99	11	110	265
		= 1.5 N.S.			= 0.5 N.S.		= 6.3 *

	Season	Spring	Summer
RIPARIAN	No. prey	77	86
	No. scats	53	58
		= 0.006 N.S.	

	Date	Week 14	Week 16	Week 18
COASTAL	No. prey	335	183	45
	No. scats	129	102	33
		= 9.3 *		

43

were deposited on stones although 15% were found on the
ground, usually along well-used runs (Fig 6b).

Table 1 also shows the total number of prey items
found in the scats collected from each site. In order to
avoid bias in analysing dietary results by frequency of
occurrence as a percentage of total occurrence, there must
be no seasonal variation in the frequency of prey per scat;
or when a number of areas are to be compared, no variation
between areas (Englund, 1965). This can be seen more
easily with reference to a hypothetical example :-

	% Frequency of occurrence		% Frequency		Actual composition	
	Lagomorph	Fish	Lagomorph	Fish	Lagomorph	Fish
AREA I						
9 monospecific scats 100% lagomorph	10	1	91	9	95	5
1 polyspecific scat 50% lagomorph, 50% fish						
AREA II						
10 polyspecific scats 95% lagomorph, 5% fish	10	10	50	50	95	5

The actual percentage of fish in the scats does
not differ between areas I and II. The frequency of occurrence
method, however, greatly enhances small percentages when scats
are polyspecific. Although the actual percentage of fish in
both areas' scats is 5%, in area I it is calculated as 9%
by frequency of occurrence and as 50% in area II.

Table 2a examines the variation in mean number of
prey items per scat using Wise's (1978) method of analysis.
This method does, however, tend to average differences and

TABLE 2b: Frequency of prey items per scat collected at each sample site.

No. prey items/ scat.	FREQUENCY						
	Chirdon Burn	Chollerford	George Hotel	River Tyne	River Tees	Riparian	Coastal
1	49	5	15	69	6	78	97
2	12	4	-	16	2	18	79
3	6	-	1	7	1	8	51
4	1	-	-	1	1	2	30
5	-	-	-	-	1	1	6
6	2	-	-	2	-	2	1
7	1	-	-	1	-	1	-

Temporal frequency of prey items per scat in the coastal and riparian habitat.

No. prey items/ scat.	RIPARIAN		COASTAL		
	Spring	Summer	Week 14	Week 16	Week 18
1	39	40	18	53	26
2	8	10	44	30	4
3	1	6	38	9	2
4	1	1	22	5	2
5	1	-	2	3	-
6	1	1	-	1	-
7	1	-	-	-	-

FIG 7   A COMPARISON OF THE FREQUENCY OF PREY ITEMS PER SCAT
FROM SCATS COLLECTED IN DIFFERENT AREAS AND AT
DIFFERENT TIMES

CHIRDON BURN

$X^2 = 2.2$

P = N.S.

RIVER TYNE

$X^2 = 13.9$

P = *

CHOLLERFORD AND
GEORGE HOTEL

RIVER TEES

RIPARIAN

Throughout Fig 7,
"x" axes refer to
number of prey
items/scat and
"y" axes to
frequency.

SPRING

$X^2 = 2.3$

P = N.S.

SUMMER

COASTAL

Week 14

$X^2 = 47.9$

P = ***

Week 16

$X^2 = 7.5$

P = N.S.

Week 18

RIVERS

$X^2 = 45$

P = *

COAST
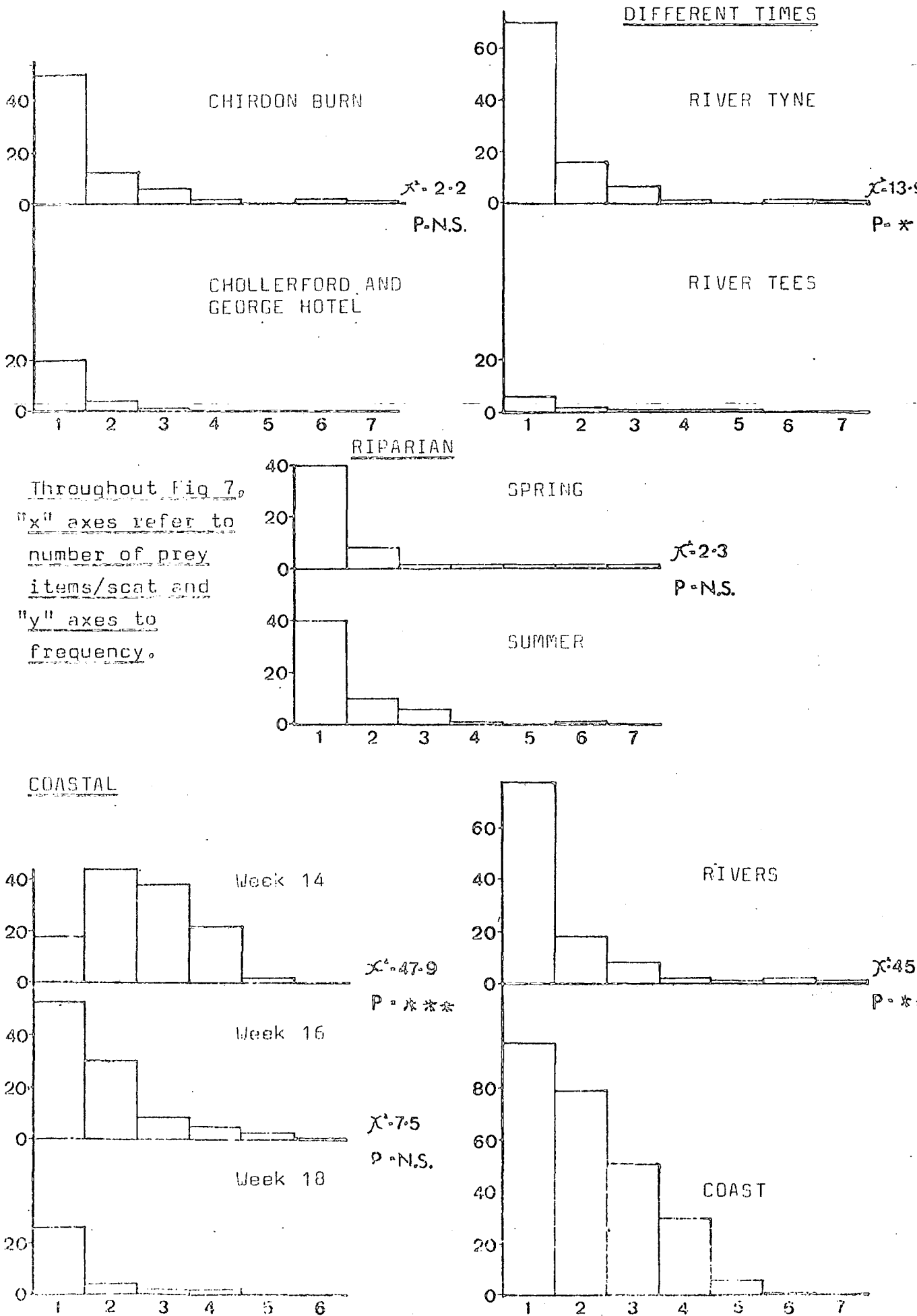
so the variation between frequency of number of prey
per scat was tested. The raw data are given in Table 2b,
and areas are compared in Fig 7.

The number of prey items per scat was similar
at the two main sites on the North Tyne ($\chi^2=2 \cdot 27$, d.f.=6,
p=N.S.). A greater number of prey items per scat was found,
however, in scats collected on the river Tees than in those
from the North Tyne ($\chi^2=13 \cdot 9$, d.f.=6, p 0·05). The data
collected between March and the end of May were amalgamated
to form a spring sample and from June and July to form a
summer sample. Comparison of the variation in the number
of prey items per scat failed to demonstrate any change
with season ($\chi^2=5 \cdot 27$, d.f.=6, p=N.S.).

Scats collected from the coastal sites were
significantly more polyspecific than those from the rivers
(Fig 7; $\chi^2=45 \cdot 13$, d.f.=6, p 0·001). In addition, there was
also temporal variation in the number of prey items per
scat on the coast. Scats from Week 14 were more polyspecific
than those from Week 16 ($\chi^2=47 \cdot 9$, d.f.=5, p 0·001), whilst
there was no difference in the number of prey per scat
between Weeks 16 and 18 ($\chi^2=7 \cdot 6$, d.f.=5, p=N.S.) as is
apparent from Fig 7.

These differences must be borne in mind when
considering both the percentage frequency of occurrence
of prey species at the coast and the variation in coastal
and riparian diets.

FIG 2a : A COMPARISON OF THE THREE METHODS OF ANALYSIS OF MINK DIET ON THE RIVER NORTH TYNE
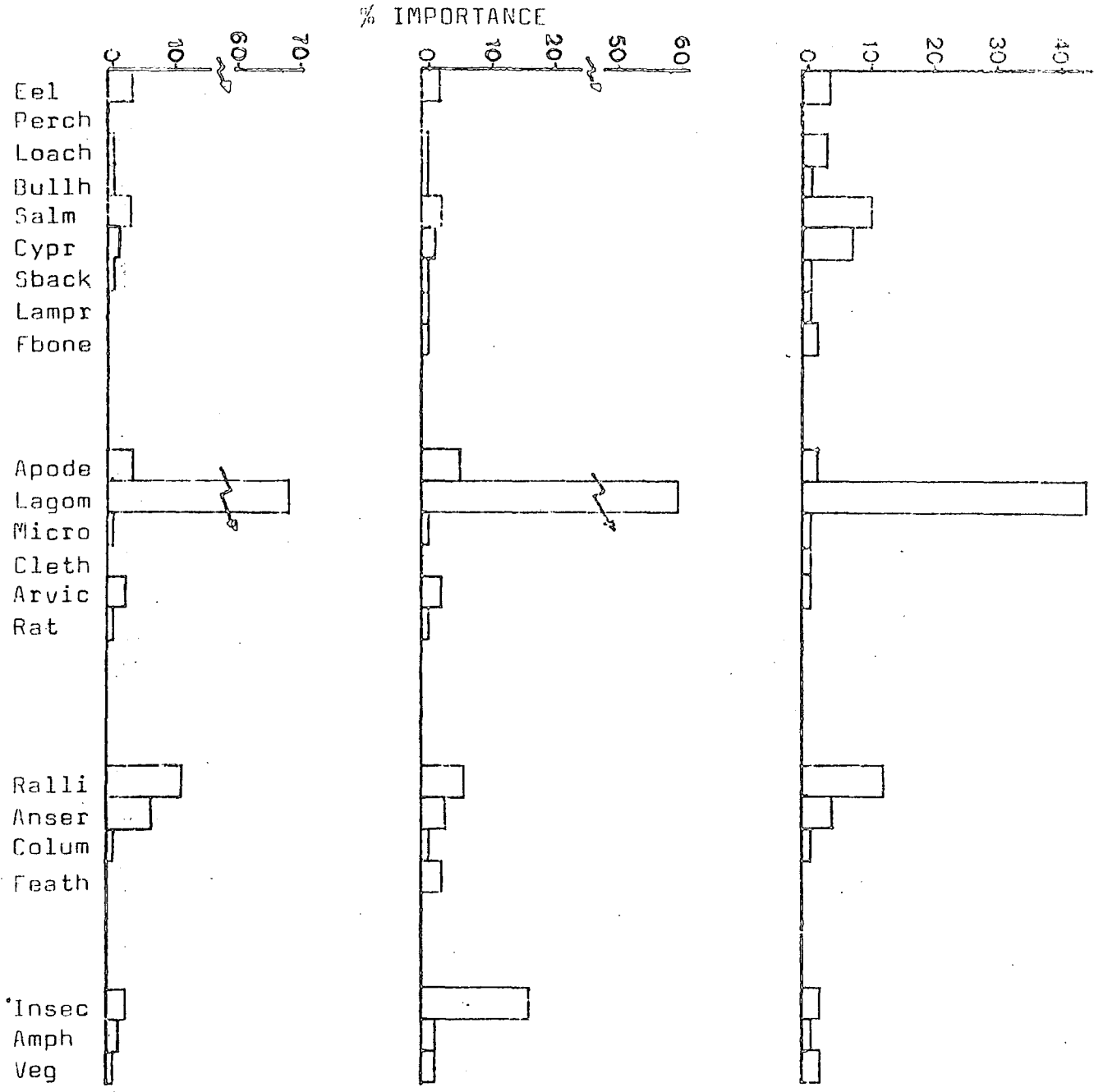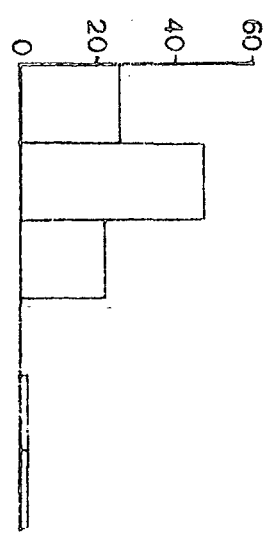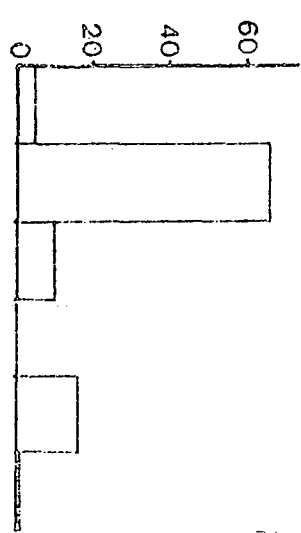
% IMPORTANCE

PERCENTAGE FREQUENCY OF OCCURRENCE

PERCENTAGE BULK ESTIMATE

PERCENTAGE CORRECTED BULK

Eel
Perch
Loach
Bullh
Salm
Cypr
Sback
Lampr
Fbone
Apode
Lagom
Micro
Cleth
Arvic
Rat
Ralli
Anser
Colum
Feath
Insec
Amph
Veg

Fish
Mamm
Bird
Amph
Invrt
Veg

FIG 8b   A COMPARISON OF THE THREE METHODS OF ANALYSIS OF MINK DIET ON THE RIVER TEES

PERCENTAGE FREQUENCY OF OCCURRENCE

PERCENTAGE BULK ESTIMATE

PERCENTAGE CORRECTED BULK
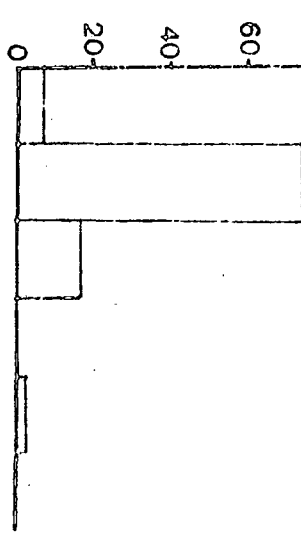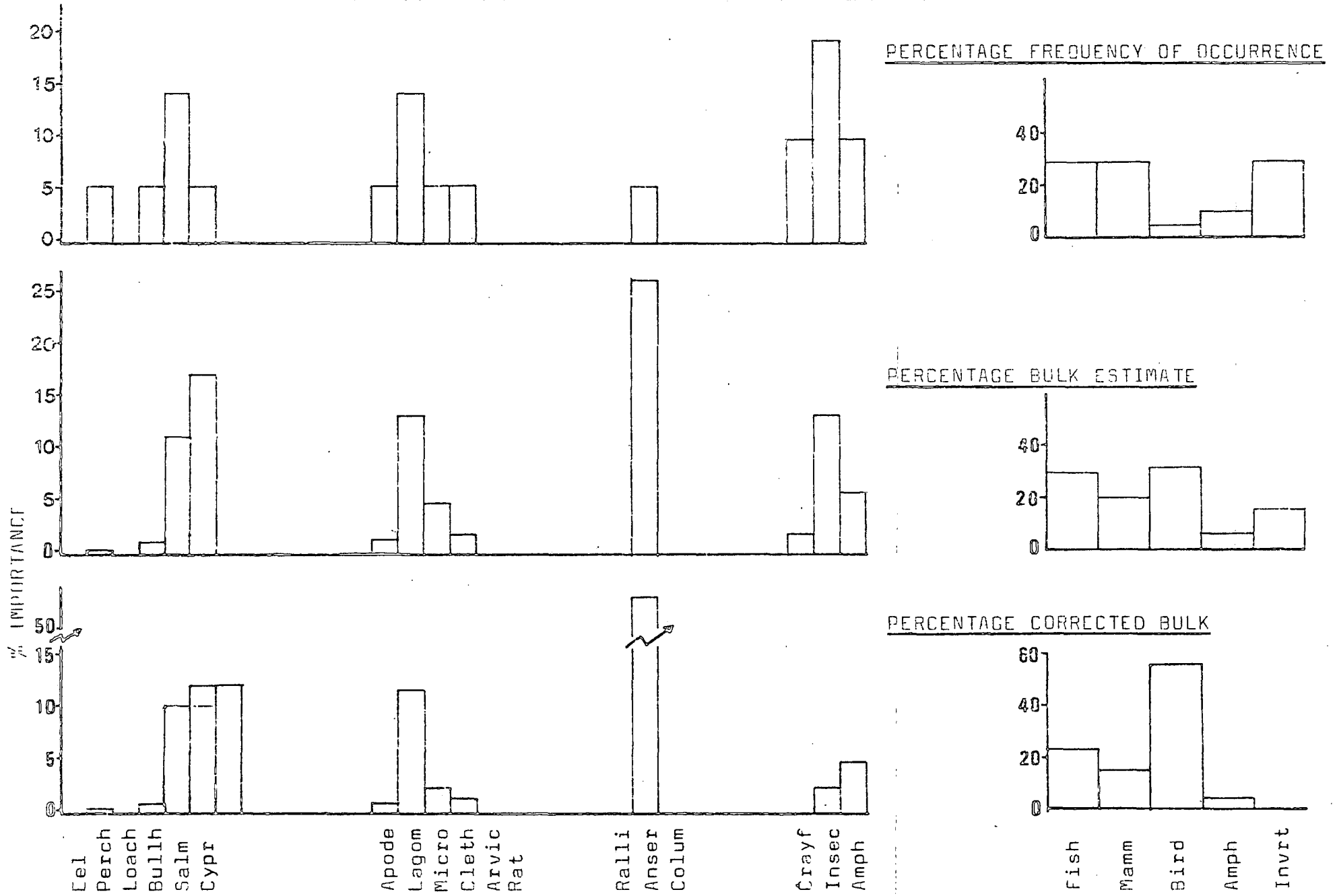
FIG 8c   A COMPARISON OF THE TWO METHODS OF ANALYSIS OF MINK DIET AT GALLOWAY
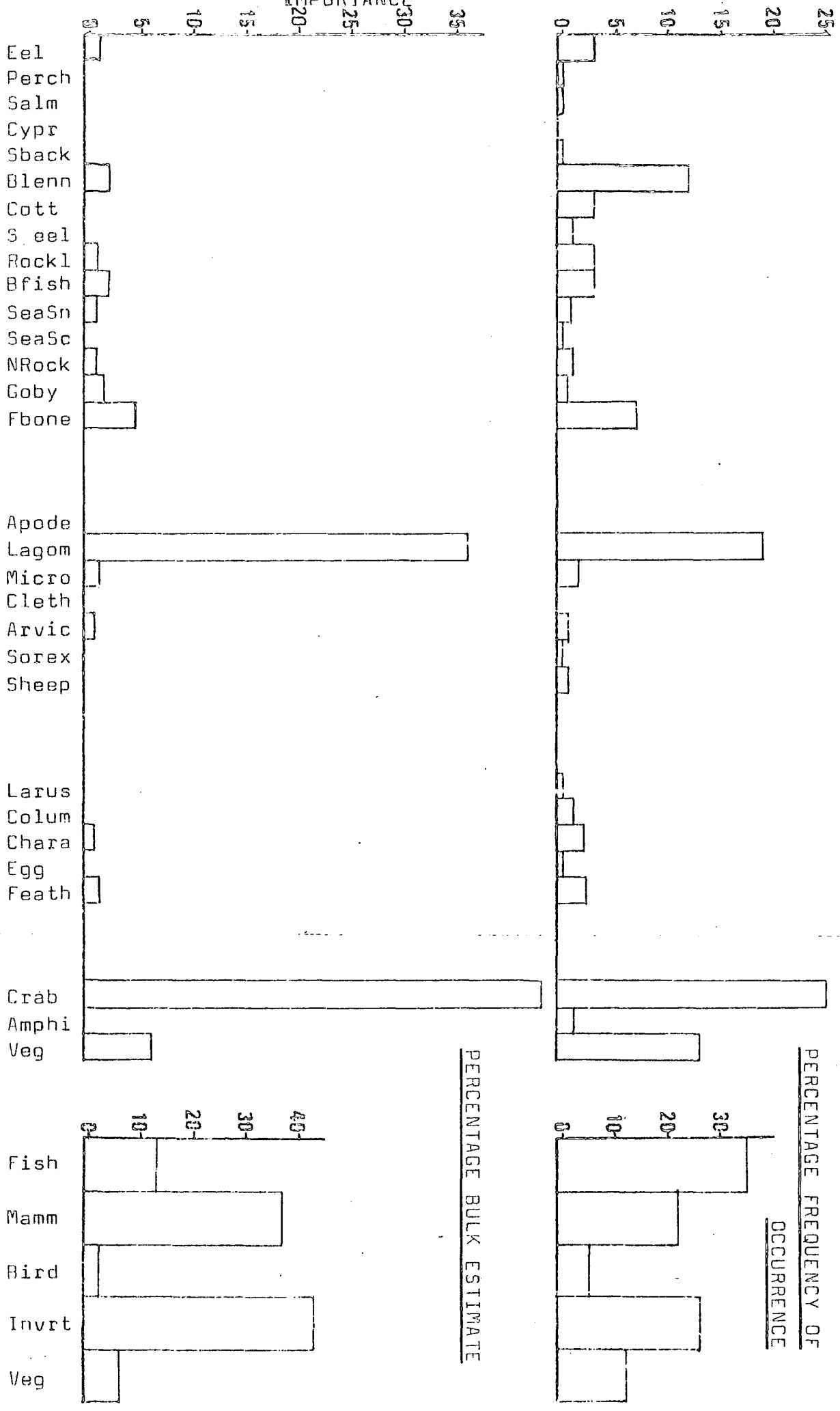
COMPARISON OF METHODS OF ANALYSIS OF RESULTS

The relative merits of the three methods of analysis (percentage frequency of occurrence, bulk analysis, and bulk analysis corrected by application of conversion factors) will be deferred until the Discussion. In this study, where possible, the results have been analysed using all three methods. For coastal data, application of conversion factors was not practical, although it had been hoped to adapt those calculated for small freshwater fish.

Figures 8a, 8b and 8c show that bulk analysis and frequency of occurrence produce remarkably consistent results in terms of percentage importance in the diet. At each study area, these two methods of analysis were compared using the Wilcoxon matched pairs signed ranks test. Overall, no significant difference between the relative importance of particular prey species calculated by either method could be detected (Table 3). This test is apparently the only means of comparing these two methods of analysis. Being a non-parametric statistic, however, a great deal of information is lost. Although it is obvious from the raw data that in the majority of cases there is no difference between the methods, in several instances the two results seem to differ considerably from a biological if not a statistical point of view. The major discrepancy arises over the importance of mammalian and crustacean prey on the rivers and at Galloway (Figure 8a and Figure 8c). The percentage importance derived from the bulk estimate is much greater than that obtained from the percentage frequency of occurrence, the bulk estimate for lagomorph being approximately double the frequency

TABLE 3: Comparison of percentage importance calculated by frequency of occurrence and bulk analysis using the Wilcoxon matched pairs signed ranks test.

Prey species	TEES		TYNE		COAST	
	%Freq. of occur.	% Bulk	%Freq. of occur.	% Bulk	%Freq. of occur.	% Bulk
Eel	-	-	3.5	1.4	3.2	1.0
Perch	4.8	0.07	-	-	0.2	-
Stone Loach	-	-	2.8	0.3	-	-
Bullhead	4.8	0.7	0.7	0.3	-	-
Salmonid	14.3	10.9	9.9	2.0	0.2	-
Cyprinid	4.8	16.9	7.0	0.9	-	-
Stickleback	-	-	0.7	0.04	0.2	0.008
Lamprey	-	-	0.7	0.07	-	-
Unid. fish bones	-	-	1.4	0.4	7.1	4.4
Apodemus	4.8	1.1	1.4	4.8	-	-
Lagomorph	14.3	12.8	43.7	59.4	19.1	35.9
Microtis	4.8	4.6	0.7	0.07	1.4	0.9
Clethrionomys	4.8	1.6	-	-	-	-
Arvicola	-	-	1.8	0.7	0.4	0.4
Sorex	-	-	-	-	0.2	0.003
Rattus	-	-	0.7	0.1	-	-
Sheep	-	-	-	-	0.4	0.02
Moorhen	-	-	12.0	5.5	-	-
Anseriform	4.8	31.0	4.2	2.5	-	-
Columbiform	-	-	0.7	0.04	0.9	0.03
Charadriiform	-	-	-	-	1.8	0.4
Larus	-	-	-	-	0.2	0.2
Egg-shell	-	-	-	-	0.2	0.2
Unid. feather	-	-	5.6	2.2	2.3	0.8
Amphibian	9.5	5.6	0.7	0.8	-	-
Crayfish	9.5	1.5	-	-	-	-
Vegetation	-	-	2.1	1.1	12.7	5.9
Insects	19.1	13.3	2.1	16.2	-	-
Blenny	-	-	-	-	11.9	2.3
Cottidae	-	-	-	-	2.7	0.05
Sand Eel	-	-	-	-	1.1	0.07
Rockling	-	-	-	-	2.7	0.7
Butterfish	-	-	-	-	2.8	1.8
Sea Snail	-	-	-	-	0.7	0.06
Sea Scorpion	-	-	-	-	0.2	0.04
Non-Rockling Gadoid	-	-	-	-	1.2	0.7
Goby	-	-	-	-	0.4	1.4
Shore Crab	-	-	-	-	25.0	42.9
Amphipods	-	-	-	-	1.2	0.3

Wilcoxon T =		20		56		77
Wilcoxon N =		12		20		26
P =		N.S.		N.S.		N.S.

estimate on the coast and one and a half times as great on
the North Tyne. Similarly, the bulk estimate for crab is
almost double that obtained using frequency of occurrence.
On the North Tyne (Fig 8a), the relative importance of
salmonids and cyprinids calculated by the bulk method was
less than that obtained from analysis of frequency of
occurrence. This tendency for underestimation of fish results
by the bulk method was, however, not so apparent on the coast
(Fig 8c). On the North Tyne and at Galloway (Figure 8a and
8c), the bulk estimate for avian prey tends to be less than
that obtained by frequency of occurrence, whilst on the Tees
(Fig 8b) the importance of Anseriforms calculated by bulk
analysis was six times the value obtained by the other method.

The differences between the frequency of occurrence
and the bulk methods are consistent within prey groups, but
vary between groups. With respect to the frequency values,
bulk analysis apparently overestimates the relative importance
of mammalian and invertebrate prey whilst underestimating
the importance of fish and the majority of avian prey.

Application of conversion factors to the bulk
estimates yields a relative importance value corrected for
the differing proportions of hard to soft parts in the
various prey species. This value may not be satisfactory
for a small sample as any errors in estimating the relative
importance can be greatly magnified if the particular
species had a large conversion factor. This is particularly
well illustrated in Figure 8b on the Tees where the corrected
relative importance of Anseriform is 56.3% compared with a
bulk estimate of 31% and percentage frequency of occurrence
of 5%. As the percentages calculated are relative, an error

for a single prey species will affect the relative
percentage of all other prey items; thus, if the result
for Anseriforms is anomalous, the other relative importance
values are likely to be lower than in reality. If this is
the case on the Tees, the percentage importance calculated
by the correction method is remarkably similar to that
calculated by the other methods.

Throughout the dissertation, only the frequency
of occurrence data will be discussed as these are amenable
to statistical techniques and provide comparison with
published data.

Results of Faecal Analysis:-

NORTH TYNE

On the North Tyne, 99 scats were collected
between March and July with a total of 142 prey occurrences
giving a mean of 1.49 ± 0.1 standard error prey items per
scat and a mean scat dry weight of 1.28 ± 0.22 g.

It is apparent from Fig 9a that mammals were the
most important prey group encountered in the diet (47.2%
frequency of occurrence) followed by fish (26.7%), bird
(10.24%), invertebrates and vegetation (2.1% each) and
finally amphibians (0.7%). Lagomorphs were the most frequent
prey item comprising 43.7% of the diet. Only single
occurrences of Rattus norvegicus, Arvicola terrestris,
Microtis agrestis and two cases of Apodemus sylvaticus
were recorded. The majority of these small mammals were all
found in the George Hotel area (Fig 9b), whilst the two
instances of Apodemus were collected downstream of the
bridge at Chollerford (Fig 9b). On the Chirdon Burn,
lagomorphs were again the only mammals encountered and here
accounted for 55.6% of the total prey taken (Fig 9b).

The most frequent fish groups were salmonids
comprising 38.8% of the total fish prey taken, followed by
cyprinids (27.8%) and eel (13.8%), with stickleback, bullhead,
stone loach, lamprey and unidentified fish bones comprising a
further 19.4%. Salmonids were rated third in overall
importance, 9.9% of the total diet. It is interesting to note
that the eel and lamprey remains were restricted to the
Chirdon Burn, whilst salmonids and cyprinids were equally
distributed between the three sites. Scats containing

bullhead, stickleback and stone loach were all collected from the Chirdon Burn.

Moorhen (Ralliform) was the most frequent species of avian prey, constituting 53% of the group and 12% of the total diet. Anseriforms accounted for 18.7% of the birds, and there was a single occurrence of Columbiform. Unidentified feathers formed a large proportion of this group (25%) and may have been from juveniles which do not exhibit the characteristic covert feathers used in identification. The diet on the Chirdon Burn (Fig 9b) had the greatest diversity of avian prey, having instances of all three taxonomic groups, whilst the majority of moorhens were encountered at Chollerford.

The amphibians, invertebrates (Coleoptera) and vegetation formed only a small proportion of the diet, and it is possible that the latter two groups were ingested incidentally whilst other prey was consumed.

TEES

On the river Tees, eleven scats were collected from two sites on a single visit in May. There was a total of 21 prey occurrences giving a mean number of items per scat of 2 ± 0.41 and a mean scat dry weight of 2.19 ± 1.02 g.

The order of importance of the major prey groups was, firstly, invertebrates, 28.5% of the diet, followed by fish and mammal prey both accounting for 28% of the diet, amphibians comprising 9.5% and birds contributing a minor 4.8% (Fig 9a). Coleoptera (19.1%) were the single most important invertebrate Order and crayfish, Astacus astacus, formed the remainder of this group. Salmonids accounted for

TABLE 4: Results of X^2 tests for a difference between mink diets on the rivers North Tyne and Tees.

Prey species	TYNE No.of scats with prey	No.of scats without prey	TEES No.of scats with prey	No.of scats without prey		
Fish	36		6			
Mammals	67		6			
Birds	32		1		34.4	***
Amphibians	3		2			
Invertebrates	1		6			
Vegetation	3		0			
Eel	5	137	0	21	0.7	N.S.
Salmonid	14	128	3	18	0.4	N.S.
Cyprinid	10	132	1	20	0.1	N.S.
Lagomorph	62	80	3	18	6.6	*
Ralliform	17	125	0	21	2.8	N.S.
Anseriform	6	136	1	20	0.1	N.S.
Amphibian	1	141	2	19	7.5	**
Crayfish	0	142	2	19	11.5	***
Insect	3	139	4	17	12.9	***

Method of calculation of   for a comparison of the importance of a single species in two areas

Area	TYNE	TEES	
No. scats with prey	a	b	a+b
No. scats without prey	c	d	c+d
	a+c	b+d	a+b+c+d

$$\text{Expected value of } a = \frac{(a+b)(a+c)}{a+b+c+d}$$

$$= \frac{(O-E)^2}{E}$$

50% of the fish prey, followed in importance by cyprinids, perch and bullhead which each constituted 16·7% of the group. Of the mammalian remains present, lagomorphs accounted for 50% of the group and were the second most important species in the diet; Apodemus, Clethrionomys and Microtis each occurred once. The amphibians were represented by a single species, Rana temporaria, and the avian group consisted of a single occurrence of Anseriform.

COMPARISON OF MINK DIET ON THE RIVERS TEES AND NORTH TYNE

A comparison of the diet of mink in two areas, when based on such a small sample size at one area (Tees, 11 scats) must be viewed with extreme caution. Bearing this limitation in mind, however, there was a significant difference in dietary composition, as can be seen from Table 4. This table also shows which prey species were responsible for the differences between the two areas. On the Tees, mink were more dependant on amphibians and invertebrates and less so on lagomorphs than on the North Tyne. It is of interest that the proportions of fish and bird taken in the two areas are not significantly different (Table 4).

SEASONAL VARIATION IN THE RIPARIAN DIET

The study period was divided into Spring (from March to the end of May) and Summer (June and July). Originally the data were divided on a monthly basis, but there was no significant variation in the diet, possibly due to the small sample size. In the Spring, 53 scats containing 77 prey occurrences were collected, whilst 58 scats with a total of 86 prey items were obtained during

TABLE 5: Results of x^2 tests for a difference in mink diet on the North Tyne between spring and summer.

	SPRING		SUMMER			
Prey species	No.of scats with prey	No.of scats without prey	No.of scats with prey	No.of scats without prey		
Fish	34		14			
Mammals	20		53			
Birds	17		15		28·6	***
Amphibians	3		0			
Arthropods	8		3			
Vegetation	1		2			
Fish	34	49	14	73	13·6	***
Salmonid	14	69	5	82	5·3	*
Cyprinid	7	76	5	82	0·4	N.S.
Eel	3	80	3	84	0·4	N.S.
Mammal	20	63	53	34	17·9	***
Lagomorph	14	69	52	35	32·5	***
Microtis	2	81	6	81	1·9	N.S.
Bird	17	66	15	62	0·6	N.S.
Ralliform	14	69	3	84	8·4	**
Anseriform	6	81	1	82	3·4	N.S.
Amphibian	3	80	0	87	3·1	N.S.
Insect	19	64	1	86	19·2	***

the Summer. There was no significant variation in the
number of prey items per scat during the two seasons
(Table 5).

During Spring, fish was the most important prey
group comprising 41% of the diet and was followed by
mammalian prey (24%), birds (20.5%), amphibians (3.6%) and
invertebrates (7.2%),(Fig 10).

During Summer, mammals became the more important
prey group, 59.8% of the total diet, followed by fish and
bird, which were of approximately equal importance, 17 and
18.3% respectively (Fig 10). At this, time no amphibians
were taken and insects contributed only 1.1% of the diet.
A more detailed analysis of fish prey showed that more
salmonids were taken in Spring compared with Summer (Table 5)
and that stone loach, bullhead and cyprinids also occurred
marginally more often in Spring.

In contrast, the mammalian group was represented
more often in scats from the Summer sample due to the vast
increase in the number of lagomorphs taken. Microtis and
Clethrionomys also increased in absolute terms, but not
significantly so.

There was no seasonal variation in the frequency of
avian or amphibian prey taken, although moorhen was
appreciably more important in Spring (see Table 5).

GALLOWAY

A total of 265 scats was collected at Galloway
on three separate occasions. The total number of prey
occurrences was 565 with a mean of 2·14 $\pm$ 0·07 items per
scat and a dry weight of 1·91 $\pm$ 0·12 g.

The order of importance of the main prey groups
was fish (34·6%), invertebrates (26·2%), mammals (21·5%),
vegetation (11·5%) and finally birds (5·4%).

Of the fish group, littoral fish provided the
bulk of the diet, 30·8 in comparison with 3·8% of freshwater
fish. Of the freshwater fish, eels were the most important
(18 occurrences) whilst single cases of perch, salmonid
and stickleback were also recorded. Of the littoral fish,
the blenny was the most important species followed by
cottidae, rockling and butterfish contributing 11 - 12 %
each of the fish total.

The main invertebrate prey was the shore crab,
providing 25% of the diet; amphipods only contributed 1·2%.
When amphipods occurred in the same scat as blennies, the
former were ignored as they are often found in the gut
contents of blennies; it is also quite possible that mink
ingested them accidentally as large numbers were never
encountered.

Lagomorphs were the single most important
mammalian prey comprising 19·1% of the total diet. Microtis,
Arvicola, Sorex and sheep (presumably carrion) all occurred
in trace amounts.

The inclusion of vegetation, mainly grass, was
an interesting feature, as it was present in large amounts
and did not appear to have been ingested accidentally.

TABLE 6: Results of χ^2 test for temporal variation in the diet of coastal mink.

Prey species	WEEK 14 No. of scats with prey	No. of scats without prey	WEEK 16 No. of scats with prey	No. of scats without prey	WEEK 18 No. of scats with prey	No. of scats without prey	Week 14&16	Week 16&18
Fish	146		47		4			
Mammals	7		85		29			
Birds	10		9		12		174·9***	11·9***
Crabs	104		26		11			
Vegetation	68		10		0			
Fish	146	189	47	130	4	41	55·0***	6·2 *
Eel	15	320	2	175	–	–	4·1N.S.	– –
Blenny	49	286	16	161	2	43	3·3N.S.	1·8N.S.
Mammal	7	328	85	92	29	16	165·8***	4·0 *
Lagomorph	7	328	77	100	24	21	145·0***	1·4N.S.
Microtis	–	–	4	173	4	41	– –	4·5 *
Bird	10	325	19	158	1	44	2·1N.S.	1·2N.S.
Crab	104	231	26	151	11	34	16·3***	2·4N.S.
Vegetation	68	267	10	167	–	–	19·3***	– –

TABLE 7: The temporal change in diversity of the diet of coastal mink

Week	n	$\frac{n}{N}$ %	% of diet formed by n
14	13	81	21·6
16	16	84	31·0
18	3	50	8·8

n = No. of species contributing less than 5% of the diet
N = Total no. of prey species consumed

Avian prey was apparently of minor importance on the coastal site, with 23.8% of the occurrences consisting of unidentified feathers. Charadriiformes were the most frequent group, comprising 33.3% of the total avian prey, whilst columbiformes accounted for the remaining 16.7% of occurrences. There was a single instance of egg-shell.

TEMPORAL VARIATION IN THE COASTAL DIET

It has already been mentioned that three separate scat collections were made at the coast. In week 14, a total of 129 scats with 335 prey items were obtained, 102 scats containing 183 items in week 16, and finally 33 scats with 45 items during week 18. There was a significant temporal variation in the number of prey items per scat, those from week 14 being more polyspecific than those from later in the season (Table 2a).

Table 6 and Figure 11 show that in respect of the main prey groups, scats collected in week 14 are significantly different from those obtained in week 16; this is particularly interesting as the scats represent the diet of a single individual. In the week 14 collection, fish was of primary importance followed by shore crab, vegetation, bird and finally mammalian prey, in that order. At the species level, significantly more lagomorph and eel were consumed during week 14. By week 16, mammalian prey had become the most important group, followed by fish, crab, vegetation and bird.

The frequency of prey groups taken during week 16 was significantly different to that from week 18, when mammal was still the most important group(Table 6), but crab had increased to 24.4%, whilst fish and bird were only 8.8%

FIG 11 TEMPORAL VARIATION IN THE DIET OF COASTAL MINK
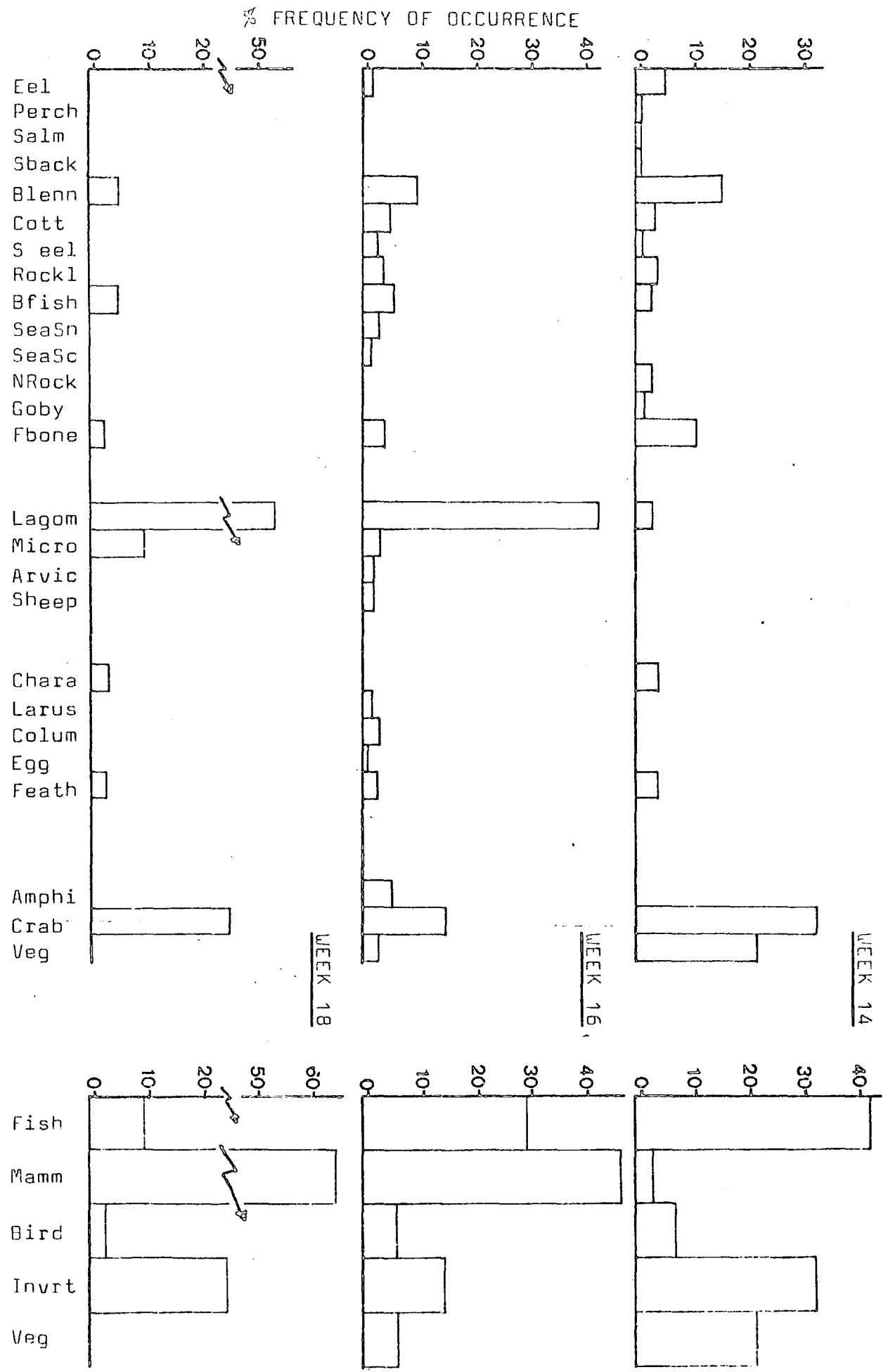
and 2·2% respectively (Fig 6). The values for crab do not differ significantly between the two dates, thus the overall difference and the apparent increase in the importance of crab is due to the change in the importance of lagomorph and fish.

In addition to the changes in importance of the major prey groups, there is some variation in the number of species taken which contribute less than 5% of the diet (Table 7).

There seems to be a tendency towards increasing specialisation from weeks 14 to 16 as initially only 22% of the diet is obtained from 81% of all the species consumed, but this increases marginally to 31% of the diet from 84% of all the species. By the third sampling date, the diet spectrum broadened and 50% of all species consumed accounted for 8·8% of the diet.

TABLE 8: Results of   tests for a difference between mink diet in a riparian and a coastal habitat.

Prey species	RIVERS		GALLOWAY			
	No. of scats with prey	No. of scats without prey	No. of scats with prey	No. of scats without prey		
Fish	42		194			
Mammals	73		121			
Birds	33		30		96·4	***
Amphibians	3		-			
Invertebrates	9		148			
Other	3		72			
Salmonid	17	146	1	564	75·5	***
Eel	5	158	18	547	0·007	N.S.
Lagomorph	65	98	108	457	30·2	***
Microtis	2	161	8	557	0·03	N.S.
Arvicola	1	162	2	563	0·2	N.S.
Apodemus	3	160	0	565	10·4	**

FIG 12   A COMPARISON OF THE DIETS OF RIPARIAN AND COASTAL MINK

% FREQUENCY OF OCCURRENCE

RIPARIAN

COASTAL

Eel
Perch
Loach
Bullh
Salm
Cypr
Sback
Lampr
Blenn
Cott
S eel
Rockl
Bfish
SeaSn
SeaSc
NRock
Goby
Fbone

Apode
Lagom
Micro
Cleth
Arvic
Rat
Sheep

Ralli
Anser
Colum
Larus
Chara
Egg
Feath

Amph
Crayf
Insec
Amphi
Crab
Veg

Fish
Mamm
Bird
Amph
Invrt
Veg
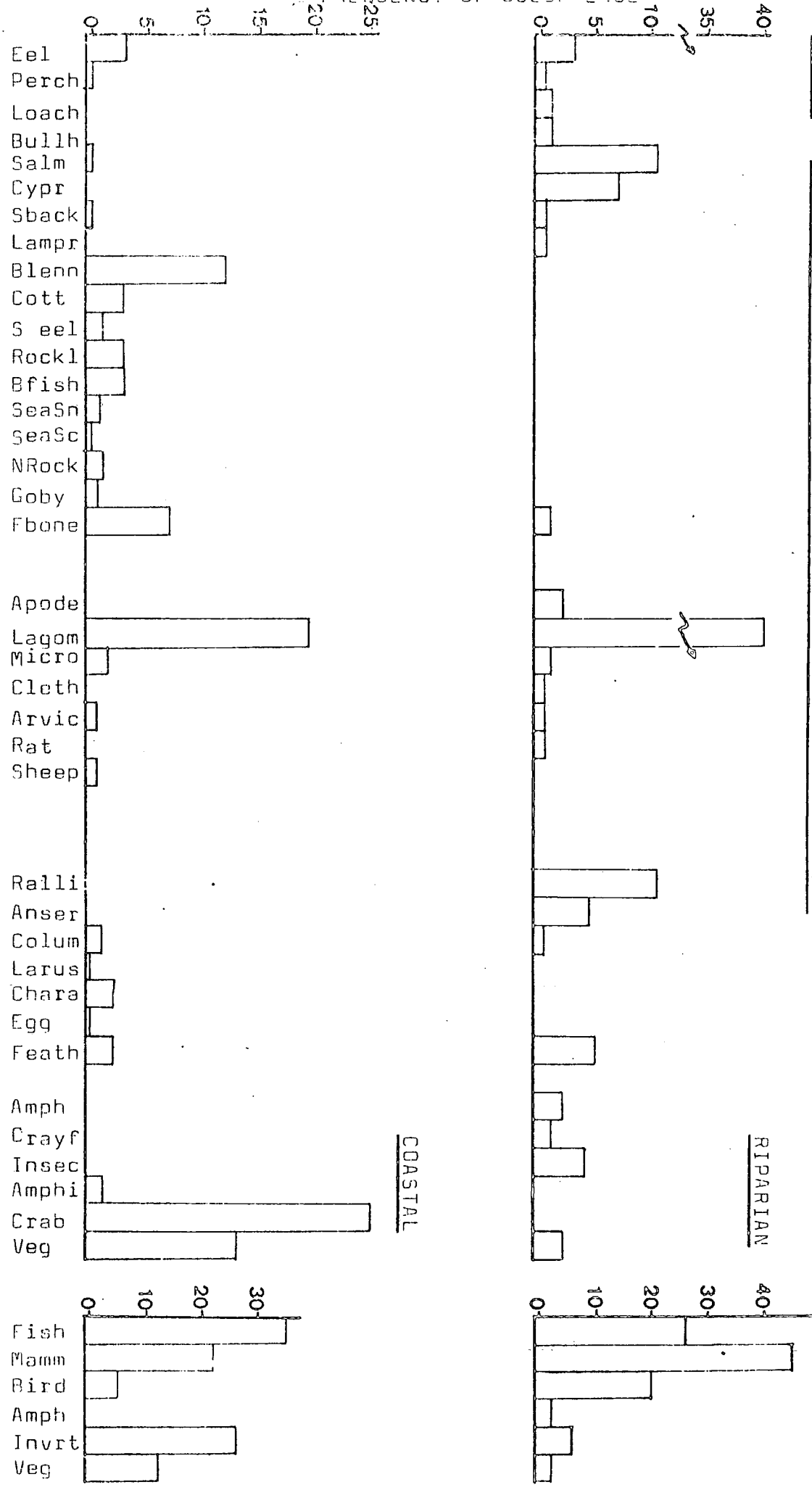
COMPARISON OF THE DIET OF COASTAL MINK WITH THAT
OF RIPARIAN MINK

Although prey availability, in terms of species
composition, differs between the coastal and riparian
habitats, as obviously there are no marine species on the
rivers and vice versa, it was thought worthwhile to compare
the frequencies of the major prey groups. It was found that
the percentage of the diet composed of the major prey groups
did differ between the two areas (Table 8).

Mammals and birds were more important on the
rivers than on the coast, and although fish had a relatively
greater importance on the coast of only 5%, crab was a
significant addition to the diet not found on the river
(Table 8).

Within groups, apart from the obviously marine
species, there are several differences in the contribution
of various species to the diet (Table 8). The proportion
of salmonids in the coastal diet is much less than on the
river. Lagomorphs form a greater proportion of the riparian
diet. Of the small mammals, only the proportions of Apodemus
differ in the two areas, being absent from the coastal diet.

DIVERSITY OF DIET

A further measure of diversity and importance
of specific items in the diet can be gained by reference to
Table 9a, which shows the total number of prey species taken
by mink in any one area and the number of species which
individually provide less than 5% of the total diet. There
is a significant difference between the total number of
prey items taken in each of the three study areas (Table 9b).

TABLE 9a: Comparison of prey diversity in terms of the
            proportion of the total number of species consumed
            which individually constitute less than 5% of the
            total diet.

Area	a)Total no. species in diet	b)No. species contributing less than 5% of diet	$\frac{b}{a}$ %	% of total diet contributed by b)
TYNE	18	14	77.8	21.0
TEES	12	7	58.3	33.6
GALLOWAY	25	21	84.0	22.3

TABLE 9b: A x^2 test for a difference between number of
            individual species consumed at each area.

Area	TYNE	TEES	GALLOWAY
No. Scats	99	11	265
Total no. prey species	18	12	25

$$= 35.5 \qquad P = ***$$

On the North Tyne and at Galloway (Table 9a),
a similar proportion of the whole diet (22%) is composed
of items which individually contribute less than 5% of the
total diet. This proportion of prey species is, however,
slightly larger on the Tees (33%). The diversity of prey
items seems to be greater at Galloway where 84% of the
total number of species taken account for only 22·3% of
the diet, whilst on the North Tyne, 78% of the total number
of prey species contribute 21% of the diet and on the Tees,
58·3% of the prey species provide 33·6% of the total diet.

FIG 13a   SIZE FREQUENCY DISTRIBUTION OF TOTAL FISH PREY

TAKEN DURING THE STUDY
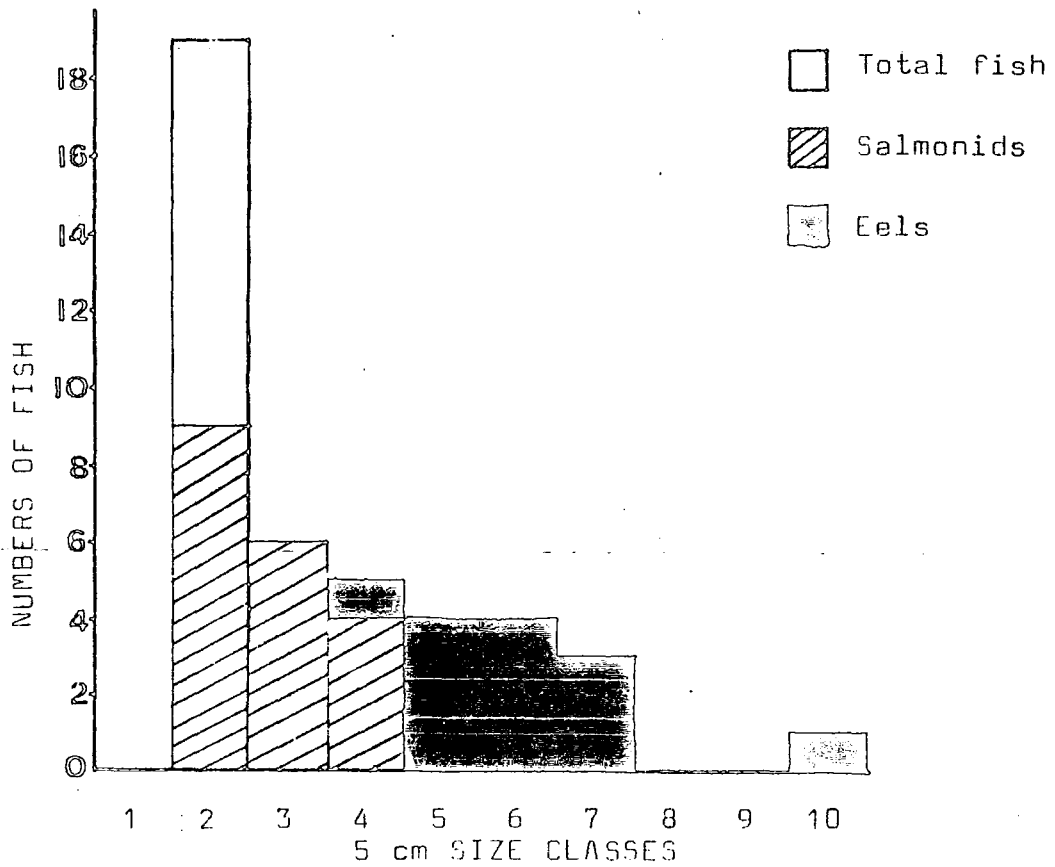
FIG 13b   MEAN SIZE OF FOUR FISH SPECIES IN THE DIET OF

MINK, CALCULATED FROM VERTEBRAL

REMAINS IN THE SCATS
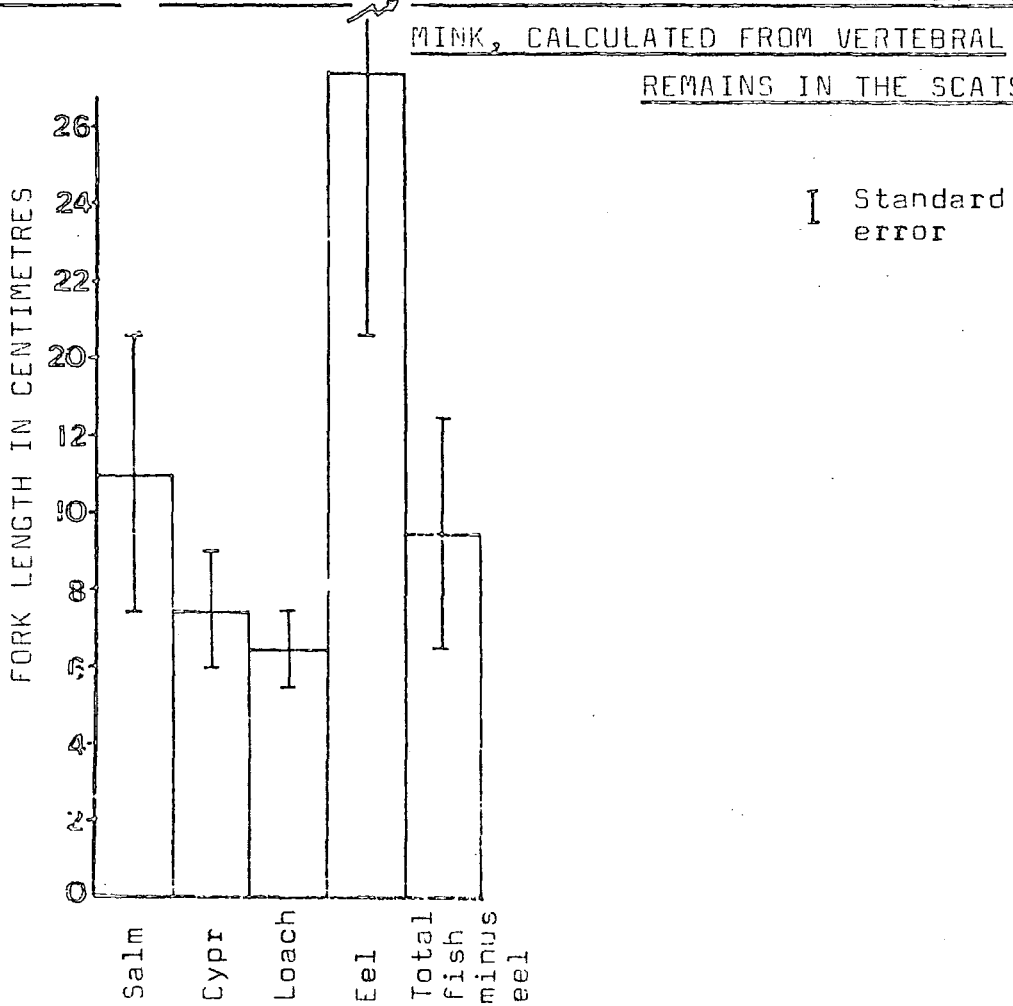
SIZE OF FISH IN THE DIET OF MINK

Using Wise's (1980) method of calculating fish fork length, from the size of the vertebrae, it was possible to estimate the size of 42 of the fish taken by mink during the study period.

It can be seen from the size-frequency histogram (Fig 13a) that fish in size class II (5 - 9.9cm) were taken most often. There were no records of fish less than 5 cm in length occurring in the scats, although as fish length was only calculated for four species, it is quite possible that small fish of other species were in fact taken.

If eels are excluded from the analysis, the mean size of fish taken was 9.62 ± 3.3 cm (Fig 13b). The mean sizes of cyprinids and stone loach were 7.48 ± 1.62 cm and 6.53 ± 1.11 cm respectively, no fish of greater than 9.9 cm being taken in either case. The majority of salmonids occurred in the second size category, with several fish in the third and fourth classes giving an overall mean of 10.95 cm; greater than that of the coarse fish.

There is apparently no significant difference in sizes of prey taken at each of the four separate study sites. Table 10 shows the mean size of salmonids taken at three sites and the mean eel size from two sites. It was not possible to estimate the size of any species other than eels at the coast due to the fact that the vertebrae of all the freshwater fish were damaged.

TABLE 10:   Mean lengths of fish taken at different study sites.

Prey	Area	Mean size $\pm$ S.E.
Salmonid	Tees	11·63 $\pm$ 4·8
	Chirdon Burn	11·15 $\pm$ 3·35
	Chollerford	10·0 $\pm$ 5·47
Eel	Chirdon Burn	30·63 $\pm$ 10·98
	Galloway	25·97 $\pm$ 4·07

DISCUSSION

Difficulty was experienced in collecting scats during the study period, particularly on the North Tyne where the river level fluctuated rapidly, rising as much as six inches in one hour (pers. obs.), and this during the summer, a season not associated with spates. Even when a single individual was tracked for four days in late August, no scats were encountered, even though the precise path of the mink was known. In the present study, the scat sample size was increased by collection from breeding dens. Chanin (1976) and Wise (1978) both collected a larger number of scats during spring and summer than in winter, but make no mention of scat collection from breeding dens. Collection of the majority of the sample from a single den has the advantage that one is possibly studying the feeding ecology of a single individual, which reduces the inaccuracy inherent in obtaining the average prey preference, but has the danger that the individual may not be truly representative of the population as a whole. This is particularly the case with a breeding female, which must be subject to very different energy and nutrient requirements, in order to suckle her young, than non-breeding animals. In addition, it is possible that once the young are weaned, they may have different requirements to those of adults.

Whilst considering the reliability of the present study, it is also useful to consider the weather patterns over the study period. Conditions were abnormally dry during April and May in Northumberland, thus the river levels were far lower than is normal. This effectively reduces the area

to be searched for fish prey, and may have increased the
susceptibility of fish to mink predation, in land-locked
pools for example. As if in compensation for the lack of
rain during April and May, the following two months were
the wettest on record for some years. This produced turbulent
spate conditions which not only made access to the banks for
scat collection impossible, but must have also removed many
scats. These conditions lasted for several days on a number
of occasions and may well have influenced the normal feeding
habits of mink. Predation on aquatic prey is likely to have
been reduced due to the strong current flow and turbulence.
In addition, the activities of many terrestrial prey species
may also have been affected. Rabbits, for example, are known
to increase their feeding rate prior to rain to compensate
for their later confinement in the burrow (Southern, 1964).

The method of analysing dietary results is also
open to discussion. The various methods available have been
introduced previously (Methods). As the relative rather than
the absolute importance of prey items was required for
comparison between sites, it was felt that the frequency
of occurrence method of analysis was most suitable,
particularly as such results are amenable to statistical
techniques and allowed comparison with published studies.

At the riparian sites, mammals comprised almost
half of the total prey intake, whilst fish and birds
respectively accounted for the remaining two quarters (Fig 12).
In the spring weeks, fish were marginally more important than
mammals and birds. As the season progressed, however, there
was a shift of emphasis, lagomorphs accounting for three-fifths
of the diet, with fish and bird items providing the other

two-fifths (Fig 10). This was due to both an increase in the number of rabbits taken and a decrease in moorhen prey. Due to freak weather conditions, it is uncertain whether the greater importance of fish in spring was due to lower water levels effectively increasing the ease of location of fish or to warmer summer water temperatures which facilitate the avoidance of capture by the poikilothermic fish prey (Gerell 1967b).

During spring and summer, the most important fish species in the diet were salmonids and cyprinids which were taken in approximately equal numbers. The mean size of cyprinids and stone loach taken were 7.5 cm and 6.5 cm respectively, several centimetres smaller than that of the salmonids (11.0 cm). On the North Tyne, Ottaway(1979) found the mean size for year class I+ stone loach to be 6.2 cm whilst that of a similarly aged trout was 11.6 cm. The size-frequency distributions of the two species were, however, quite different, stone loach age classes I and II were the most abundant, whilst the majority of the trout were in the 0+ age class, with a mean size of 4.6 cm. From these results, it appears that mink may be taking the most frequent size class of loach encountered whilst actively selecting larger salmonids. Mann (1971) found that 0 year salmonids in a trout-stream in Dorset did not reach 6 cm until late July/August. Fish are known to grow more slowly in Teesdale than in Dorset (Crisp, pers. comm.) and it is possible that development would be similarly delayed on the North Tyne,so that year class 0+ salmonids would be less than 4.5 cm during the study period and may pass unnoticed; thus, effectively the most frequent size class encountered would

be the 10 cm class.

The estimation of fish sizes from scat analysis
should only be considered in the context of mink feeding
behaviour. Several researchers (Chanin,1976; Wise,1978)
have reported that whilst mink tend to consume small fish
whole, they only take the flesh from larger fish, and hence
these size classes may be underestimated in scat analysis.

Eels were completely absent from the diet on
the Tees and occurred at only one site on the North Tyne,
despite their known presence in the rivers. This under-
representation may simply have been the result of a small
sample size as Chanin (1976) and Wise (1978) both found
that the importance of eels increased in the summer.

During summer, the only mammalian prey taken on
the rivers was lagomorph (Fig 10). This is in agreement
with Wise's (1978) results; she noted that lagomorph
became more important during spring and summer. The increase
in importance of lagomorph in the present study during the
summer was partly due to an absolute increase in the amount
of lagomorph, but also due to a decrease in the proportions
of fish and invertebrates taken. The breeding season of the
rabbit starts in January and lasts until the end of June,
reaching a peak in April/May. This would seem to be at odds
with a summer increase in the importance of rabbits in the
diet from June to July. The spring young start breeding,
however, when aged three months and the gestation period
period is 28 - 30 days after which weaning does not occur
for three weeks. It is thus possible that the population
may show an increase towards the end of the breeding
season, namely June and July.

Apodemus, Clethrionomys, Microtis, Arvicola

and Rattus were only encountered in the diet infrequently

(Fig 12). Akande (1972), Chanin (1976) and Cuthbert (1979)

all found rodents, particularly voles, to be the most

important mammalian prey, and Wise (1978) noted that small

mammals accounted for just under half of the total

mammalian prey. The low incidence of non-lagomorph mammals

in the present study is in contrast to the results of

previous workers and may be explained by the fact that all

previous studies have been on the annual diet.

It is interesting to note that no insectivores

were taken on the rivers. Several authors, Newby (1951),

Lockie (1961) and Moors (1975) have reported an avoidance

of these species by carnivores. All work on mink in this

country has shown, however, that they take insectivores

in relation to their abundance. Their absence in the

present study may simply be a corollary of the general low

incidence of small mammals in the diet.

Avian prey formed almost a quarter of the total

diet throughout spring and summer. The most important species

during the spring was moorhen, superceded by Anseriformes,

probably mallard, during summer. This may reflect a slight

difference in the breeding behaviour of the two species.

Wood (1974) reports that moorhen breed from late March to

early August with a peak from the end of April to mid-May,

whereas Ogilvie (1964 in the Atlas of Breeding Birds in

Britain and Ireland) reports that the peak of mallard

breeding is from mid-April to July, rather longer than that

of the moorhen. The more likely explanation, however, seems

to be one of local abundance; the majority of scats which

contained moorhen were collected from the George Hotel
area of the North Tyne whilst those containing mallard
were from the Chirdon Burn alone (Fig 9b).

The three occurrences of amphibian, Rana
temporaria and/or Bufo bufo were indistinguishable and
were all encountered during the spring. Gerell (1967b)
also found a spring peak in amphibian prey and postulated
that they formed a buffer food refuge which is exploited
during the change from one major prey type to another.

In discussing the results from Galloway, it is
important to remember that scats from week 14 were more
polyspecific than those collected during June, since this
tends to overemphasise the importance of minor items
occurring in polyspecific scats whilst underestimating
major ones. The amalgamation of data from week 14 with
that from weeks 16 and 18 results in a lower value for the
relative importance of lagomorph than is the true case, as
this prey item constituted 60% of the monospecific scats.
In addition, on a numerical basis, fish attain a greater
overall importance. The bulk estimate should account for
this, and apparently does so, the relative frequency of
occurrence of fish being 39.8% whilst that obtained by
bulk analysis was 14.21%.

There was a decrease in the relative importance
of fish, bird and vegetation in the diet over the three
successive collection dates, whilst the importance of
mammalian items steadily increased (Fig 11). The proportion
of crab in the diet fluctuated, reaching the lowest level
in week 16. Although the relative importance of crab was
apparently higher in week 18, there was no significant

difference in its frequency over these weeks; thus, the relative increase of crab must have been due to a decrease in the importance of one of the other prey items. This is most likely to have been caused by the decrease in fish because, although the frequency of mammals decreased, their relative frequency in scats increased. It is possible that the decrease in the importance of fish during the study period may simply be an artefact caused by the high degree of polyspecificity of scats collected in week 14, which would tend to inflate the importance of fish in that period. It can also be argued, however, that in order to increase the polyspecificity, the numbers of fish taken must also have increased.

The temporal variation in the diet merits further attention as it relates mainly to a single mink, and a breeding female at that. The major feature was a decrease in the diversity of prey associated with a change in emphasis from crab to lagomorph (Fig 11). Due to the smaller sample size in week 18, the fall in diversity may simply have been an artefact. The change from crab to lagomorph was convincing, though, particularly if the large proportion of vegetation which provided no nutrients is discounted from week 14. The vegetation was included in calculations of the relative importance of various prey items for completeness, following Wise (1978). On reflection, however, the validity of this practice is questionable as the vegetation does not apparently contribute to the diet. If it is removed from the analysis , the percentage importance of crab in week 14 increases from 32% to 40.5%, whilst the other items also increase minimally in relative importance.

As kits were seen at this site during May
(Watson, pers. comm.), and as Gerell (1969) reports weaning
at five weeks of age, it was calculated that scats collected
from late May coincided with the suckling period. In the
present study, the increase in lagomorph in the diet from
June 2nd onwards apparently coincided with the weaning
period. Gerell (1969) noted a female mink delivering prey
to the den at this time. Thus the increase in lagomorph
may have been the result of a preference for prey which was
relatively easily transported and which provided a large food
source. The increase in lagomorph may, however, have been in
compensation for a decrease in the absolute availability of
crabs in May/June as was reported by Naylor (1962).

Between weeks 14 and 16 when fish formed an
appreciable part of the diet, there was little marked
variation in the importance of individual species, although
the frequency of eels decreased significantly over this
period, whilst the apparent decrease in blennies from week
14 to 16 was not significant. This shift in emphasis for
fish could simply be due to a greater availability of
lagomorphs. It is interesting that blennies are by far the
most common of the rock pool fish eaten. An attempt to assess
the availability of littoral fish at low tide showed blennies
to be encountered most frequently.

The mammalian prey was composed almost entirely
of lagomorph with a few occurrences of Microtis, Arvicola
and a single Sorex, but with a notable lack of Apodemus,
Clethrionomys and Rattus. Lawrence and Brown (1974) note
that Apodemus is more common when Microtis is absent from
the area, although a trapping program would be required to

substantiate this. The absence of <u>Rattus norvegicus</u> in the
diet is surprising as there is a farm in the study area,
although this food source may only be exploited when all
else is rare. It is possible that there is insufficient
habitat cover for <u>Clethrionomys</u>, but the most plausible
reason for its absence is simply one of sample size combined
with a glut of lagomorph. Cuthbert (1979) has suggested
that the paucity of <u>Clethrionomys</u> and <u>Apodemus</u> in the diet
is due to their burrowing habits and use of dense cover
making them less accessible. The increase of importance of
lagomorph in early June is similar to that found on the rivers
and may again be due to increase in juvenile rabbits available
at this time. Several brown hares were encountered at the
coastal site and two carcasses were found close to the
breeding den. Although mink could probably kill an adult
hare, it is possible that these prey were obtained as carrion;
sheep carrion was apparently also taken.

Results from other studies of the diet of coastal
mink are in accordance with the results presented here.
Gerell (1968) noted that <u>Microtis</u> and <u>Arvicola</u> were the most
frequent mammalian items in the diet of mink on some Swedish
islands, whilst Cuthbert (1979) found that lagomorphs,
common rats and <u>Microtis</u> were the most frequent mammalian
species on his coastal site in Scotland.

The three groups of birds encountered in the diet
were Charadriidae, Laridae and Columbidae. The relative
importance was lower than that found by Cuthbert (1979). The
major avian prey item in his study was Laridae whilst Charidae
were most important in the present study. Of the thirty
occurrences of feather, almost half were unidentifiable and

therefore possibly from juvenile birds. Gerell (1968)
found two peaks of bird predation, in March and June. In
the present study, the percentage relative importance was
marginally greater in week 14, but probably not significantly
so.

Carcinus was the major invertebrate prey and was
the only species of decapod encountered. Whilst this is in
accord with Gerell's (1968) and Cuthbert's (1979) results,
Watson (1978) noted that otters took a large number of the
velvet swimming crab, Portunus puber. This may have been
due to different habitat conditions or to different hunting
behaviour of otters in comparison with mink.

The large amount of vegetation present in scats
collected during week 14 is interesting. The vegetation was
mainly grass and although it had obviously passed through
the digestive tract, it was undigested. During the course of
radio-tracking studies at the riparian site, mink were seen
to purposely ingest grass. Both Chanin (1976) and Wise (1978)
found that grass comprised only a small proportion of the
diet and they concluded that it was ingested accidentally.
It is possible in the present study that the mink collected
it as nesting material and accidentally ingested some, but
this seems unlikely. Another possibility is that grass is
ingested to form a cover around fish bones to prevent damage
to the intestine, but this too seems improbable, since, were
it the case, one would expect a higher incidence of vegetation
in the scats from all localities and throughout the year
when fish are consumed. A final suggestion is derived from
the correlation between crab and grass in the diet. It is
possible that the grass acts as an anti-emetic counteracting

the ingestion of quantities of sea-water or as roughage.

Gerell (1968) found fish to be the most important
coastal prey item, followed by arthropods and finally
mammals and birds. In Cuthbert's (1979) study, C. maenas
was the most important prey item, accounting for 33% of
the diet, followed by fish, mammals and birds. The present
study is similar to that of Gerell's (1968) in establishing
the primary importance of fish. Different species were
represented, however, and the total relative importance
was less, possibly because lagomorph and crab are more
important during summer and thus a comparison of a
seasonal with an annual study may produce spurious differences.

The greater importance of fish in the coastal diet
than on the rivers (Fig 12) may be somewhat inaccurate due
to an overestimation of the importance of fish resulting
from the use of frequency of occurrence analysis and the
differing polyspecificity of the scats. It may also, however,
be due to differences in fish behaviour; in the rivers, warm
summer water facilitates rapid movement, whilst on the coast,
the majority of fish taken are of the rock pool species
which possibly do not depend so much on sustained speed of
movement for escape. In addition, the availability of crab
on the coast must reduce the mink's dependence on fish and
mammalian prey.

The diversity of the coastal diet is greater
than that in a riparian habitat, though it is unclear whether
this is because the coastal habitat is less optimal and thus
food harder to obtain or whether it is simply a reflection
of a greater diversity of available prey. Both Kruuk and
Hewson (1978) and Watson (1978) found the density of otters

to be higher in a coastal area than in a riparian habitat suggesting a more optimal environment. Hatler (1971), whilst conceding that potential food sources are widely and abundantly distributed, points out that temporal restrictions are placed on hunting by the tidal cycle and notes that this can result in considerable stress on mink at certain times of the year.
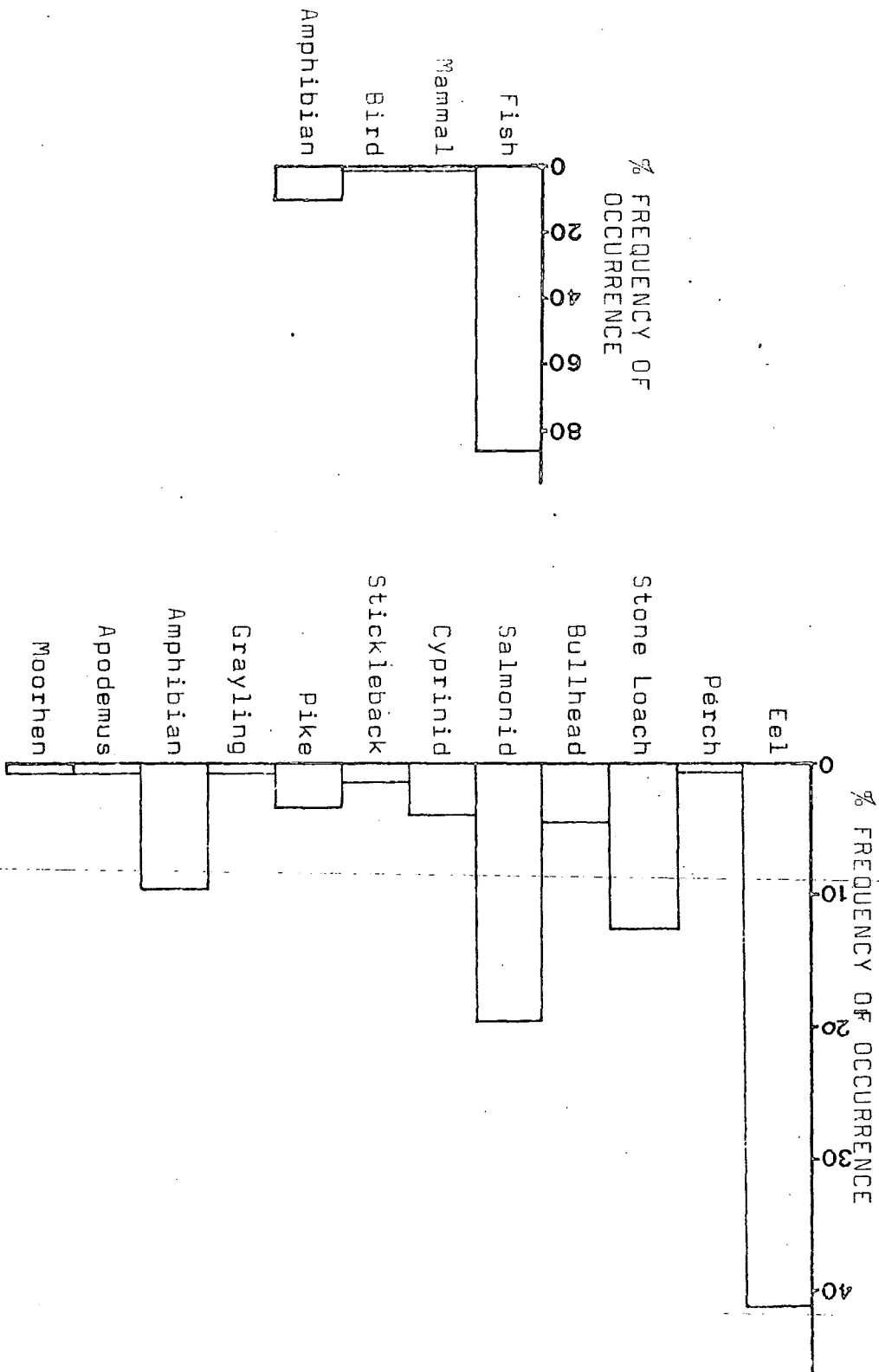
As no measure of the density of the prey species available has been obtained, the discussion of mink diet has necessarily been very superficial. It seems reasonable to assume, however, that during spring and summer the numbers of many of the prey species will be at their most abundant; thus apparent differences in numbers taken may well be the result of specific preferences rather than simply reflecting absolute availability. All the species of small mammals which appeared in the diet on the North Tyne were trapped with relative ease, hence the explanation for the large proportion of lagomorph in the diet may simply have been that this was a preferred food, when availability of all species was similar, or that more scats are produced from a rabbit kill than from small mammals.

The present results differ from those of previous workers at the specific level, whilst the importance of major groups, fish, mammal and bird, is fairly consistent. The high incidence of lagomorph seems to be the only major anomaly at the species level and this may be partially due to the fact that Day and Linn (1972), Akande (1972), Chanin (1976) and Cuthbert (1979) only presented data for the annual diet.

The majority of scats in the present study were

Total prey occurrences = 131

Total spraint number = 80

% FREQUENCY OF OCCURRENCE

0 20 40 60 80

Fish
Mammal
Bird
Amphibian

% FREQUENCY OF OCCURRENCE

0 10 20 30 40

Eel
Perch
Stone Loach
Bullhead
Salmonid
Cyprinid
Stickleback
Pike
Grayling
Amphibian
Apodemus
Moorhen

FIG 14   PERCENTAGE FREQUENCY OF OCCURRENCE OF PREY ITEMS
IN THE DIET OF THE OTTER ON THE RIVER NORTH TYNE

collected from breeding dens and this may have introduced
bias in the results. Gerell (1969) noted that a female mink
became more diurnal in the post-parturition period, whilst
the radio-tracking study described in Appendix I showed that
a juvenile male was apparently diurnal; hence these animals
may be subject to a slightly different prey availability
than those which have provided the results of previous studies.

An analysis of otter diet from spraints collected
on the North Tyne at the same time as this study, was made
available by N. Pautard (1980). Comparison of Figure 8a with
Figure 14 shows there to be minimal overlap between the diet
of these two predators. The principal prey group in the otter
diet was fish, comprising 86.2% of the total diet, whilst
fish were of secondary importance to mink, forming only
26.7% of the total diet. Amphibians formed 9.2% of the otter
diet but only 0.7% of mink diet. Salmonid, cyprinid and
stickleback were taken in similar proportions, although even
then, the frequency of occurrence in the otter diet was
double that in the mink's diet. The mink's food spectrum was
apparently wider than that of the otter as mink consumed a
total of 18 different prey species of which 15 comprised
individually less than 5% each of the diet and accounted
for only 21% of the total diet. In contrast, the otter
concentrated on a total of 12 prey species of which 8 formed
only 16% of the total diet. Thus the otter obtains 84% of
the diet from only four prey species and must therefore
be a specialist predator. 89% of the otter's diet consists
of completely aquatic prey, and a further 10% of semi-aquatic
prey, whilst the mink's diet is composed largely of
terrestrial prey (50% of the diet) with aquatic and semi-
aquatic prey forming a further 25% each. A further separation

occurs in the size range of fish selected; the mean size
of salmonids taken by mink is $11 \cdot 0 \pm 0 \cdot 8$ cm, whilst the
mean taken by otter is nearer 15 cm.

From these results, it is apparent that mink
and otter do not compete for food during the summer in this
study area. All the authors who have previously studied this
problem in Britain have come to a similar conclusion. The
only possible instance of competition for dietary requirements
was reported by Erlinge (1969) in a Swedish habitat during
the winter months when conditions are likely to be more
extreme.

A comparison of the results from the present
investigation of the diet of coastal mink with those of
Watson's (1978) study of the diet of coastal otters in
Shetland indicates a distinct separation of diet. For the
period May-June, Watson (1978) calculated that fish comprised
$84 \cdot 8\%$ of the diet with the remaining $15 \cdot 2\%$ being accounted
for by Crustacea. In contrast, the mink took $34 \cdot 6\%$ of its
diet as fish, crab accounted for $26 \cdot 2\%$, mammal $21 \cdot 5\%$,
bird $5 \cdot 4\%$ and vegetation $11 \cdot 5\%$. Within the fish group the
most important species to the otter were, in rank order,
butterfish, Yarrell's blenny and rockling, whilst the
common blenny, eel and butterfish were the most important
fish species to the mink, although contributing a much
smaller proportion of the diet overall.

Watson (1978) noted that the diet of a juvenile
otter was different to that of its mother and suggested
that this was because the cub was not very adept at catching
the fish prey preferred by the mother and therefore was
forced to take crabs and other prey which are less favoured

by its parent. It is possible that, if the mink is only
a recent colonist, it too has not learned to cope with swifter
prey species. It does seem more likely, however, that the
mink's inferiority to the otter as an aquatic predator in a
riparian habitat also extends to the coastal habitat. If this
is the case, there may be cause for alarm that the mink will
compete with otter cubs which take a large proportion of crab.

From a comparison of these two studies, it seems
that the mink is less completely a coastal animal than the
otter and, in the event of competition, may be able to take
advantage of a mammalian prey food refuge.

Although the present study is incomplete, the
trends indicate that there is a change in the composition of
mink diet in the riparian habitat between spring and summer.
Initially, the order of importance of the major prey groups
was fish, mammal, bird, amphibian and invertebrate, although
during the summer the mammal group doubled in importance.
This change seems to be mainly due to a variation in prey
availability coupled to some extent with preference for
particular species.

At Galloway, where the majority of scats were
obtained from a single breeding den, there was a temporal
variation in the diet, lagomorph increasing in importance
during the sampling period whilst both fish and crab declined.
It was postulated that this variation may have been due to
the varying requirements of a female and kits during the
breeding season.

On the rivers, half the diet was composed of
terrestrial species with the remainder equally divided between
aquatic and semi-aquatic prey. On the coast, however, the

proportions of aquatic, semi-aquatic and terrestrial prey types were approximately equal.

The radio-tracking data showed that numbers of scats encountered and padding are unreliable indicators of mink presence or absence. In addition, the juvenile male tracked exhibited a diurnal activity pattern which may have been a result of maternal influence. It engaged in much exploratory behaviour indicating either the establishment of a territory or the initiation of a dispersive phase. From the random use of den sites it was postulated that denning may be related to either prey capture or convenience.

There was apparently no dietary competition between the riparian mink and otters and the excess of potential den sites would seem to preclude competition for lying-up places. It seems unlikely that the mink is a potential competitor with the otter in a coastal environment, although any dietary overlap is most likely to occur with the otter cub, when the latter would be most likely to suffer from dietary competition.

Chollerford

KEY

trap sites

Radio-tracking days

Day 1
Day 2
Day 3
Day 4
Day 5

sycamore trees

Scale 1:10,560

0   500   1000 yards

Walwick
Grange
Farm

Wall Mill

APPENDIX 1 :   RADIO-TRACKING RESULTS

The activity patterns of mink were compiled from
two separate periods of radio-tracking. Mink A was tracked
continuously for a total of three days in April and Mink B
for four days at the end of August. The former was a Silver-
Blue adult male and Mink B a Silver-Blue juvenile male.
Both were trapped along the same 100 m length of the North
Tyne at Chollerford (A at trap 3, B at trap 2, Fig 16) and
taken to Durham to be fitted with radio collars.

The animal was anaesthetised using "Vetalar"
(ketamine hydrochloride) which took effect within five
minutes. A shallow collar of fur was shaved from the neck
of the mink and the AVM radio collar containing a SM1
transmitter at 173 MHz was attached. These transmitters had
a potential battery life of six months and weighed 12.99 g
representing less than 1.4% of the mink's body weight. A
Beta light was attached to Mink B's collar to aid location
at night.

Mink A remained in captivity for two weeks after
capture, whilst B was released after 14 hours, once the
effects of the anaesthetic had worn off. Tracking was carried
out on foot using a hand-held Yagi aerial, the equipment had
a theoretical range of 2 km, but in practice this was
reduced to 500 m. A was tracked virtually continuously
during the 24 hour period with only a short break of 2 to
$2\frac{1}{2}$ hours between 12.30 to 2.30 pm. Mink B was not tracked
overnight after observations had shown that there was
apparently no activity during this period. N. Dunstone and
S. Pickering have kindly made the observations on Mink A

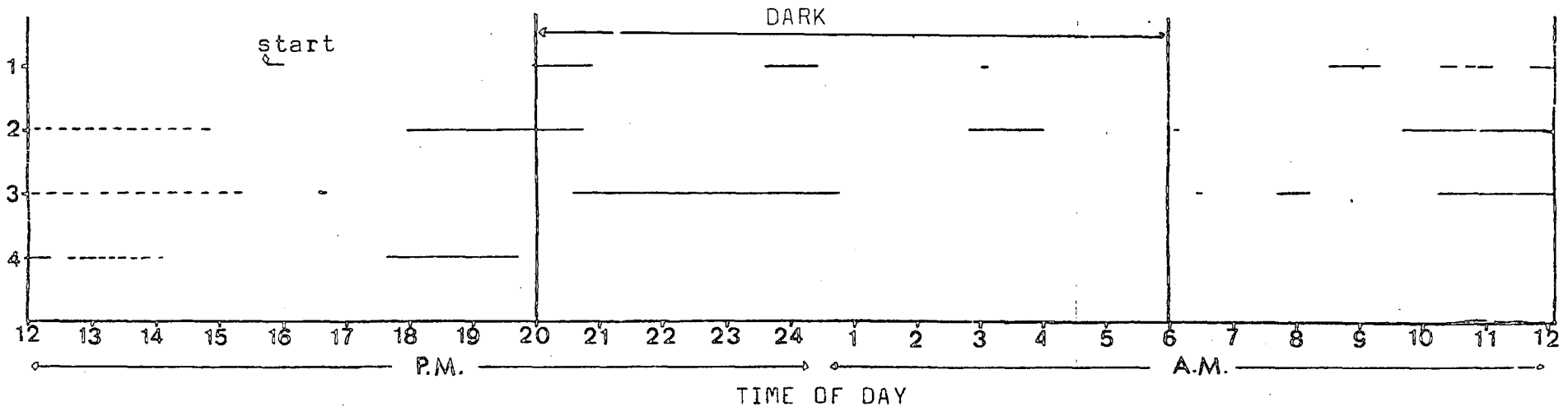FIG 15a   A DIAGRAM TO SHOW THE ACTIVITY PATTERNS OF TWO RADIO-TAGGED MINK

---- No observations
—— Activity
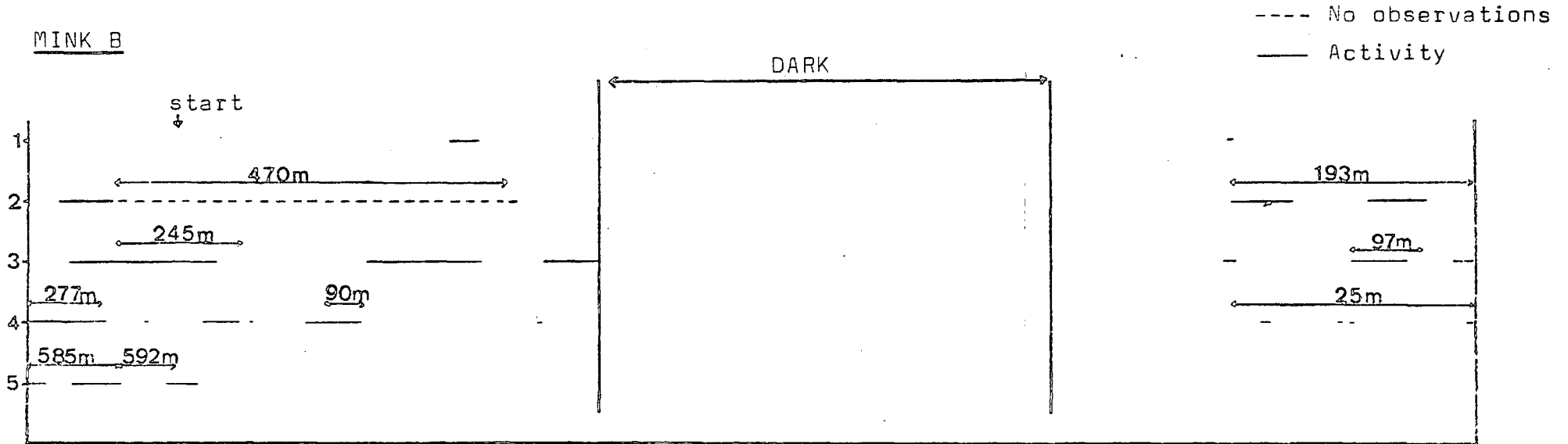
MINK B

(For mink B, figures associated with bouts of activity refer to distance travelled
in metres during that period)

MINK A

TRACKING DAYS

TIME OF DAY

95

available for comparison with those obtained from tracking
Mink B.

ACTIVITY PATTERN

Figure 15a shows the activity patterns of the two
males over the period for which they were tracked. Activity
was calculated as a percentage of time spent inactive, the
results are shown in Table 11.

TABLE 11:   Activity as a percentage of time spent inactive.

| Animal	am.	pm.	Night	Day
A	47%	51%	27%	10%
B	11%	36%	—	17%
B*	12%	46%	—	—

* activity as a percentage of hours of daylight.

The day was arbitrarily divided into two twelve
hour periods from 12.01 am to 12.00 pm (am) and 12.01pm to
12.00 am (pm). Mink A was equally active during both periods,
however Mink B was markedly less active during the am period.
Activity was then calculated as a percentage of time
inactive, but divided on the basis of hours of darkness
and hours of light, A was relatively more active during the
night whilst B was completely inactive during this time.

Figure 15b shows the total activity per hour over
the whole tracking period and the mean activity for each hour
of the 24 hour period. From both this and Fig 15a it is
apparent that Mink B was completely diurnal whilst Mink A
was marginally more active at night than he was during the
day.

Both mink appeared to have two periods of more

FIG 15b   DISTRIBUTION OF TOTAL AND MEAN ACTIVITY THROUGHOUT THE TWENTY-FOUR HOUR PERIOD
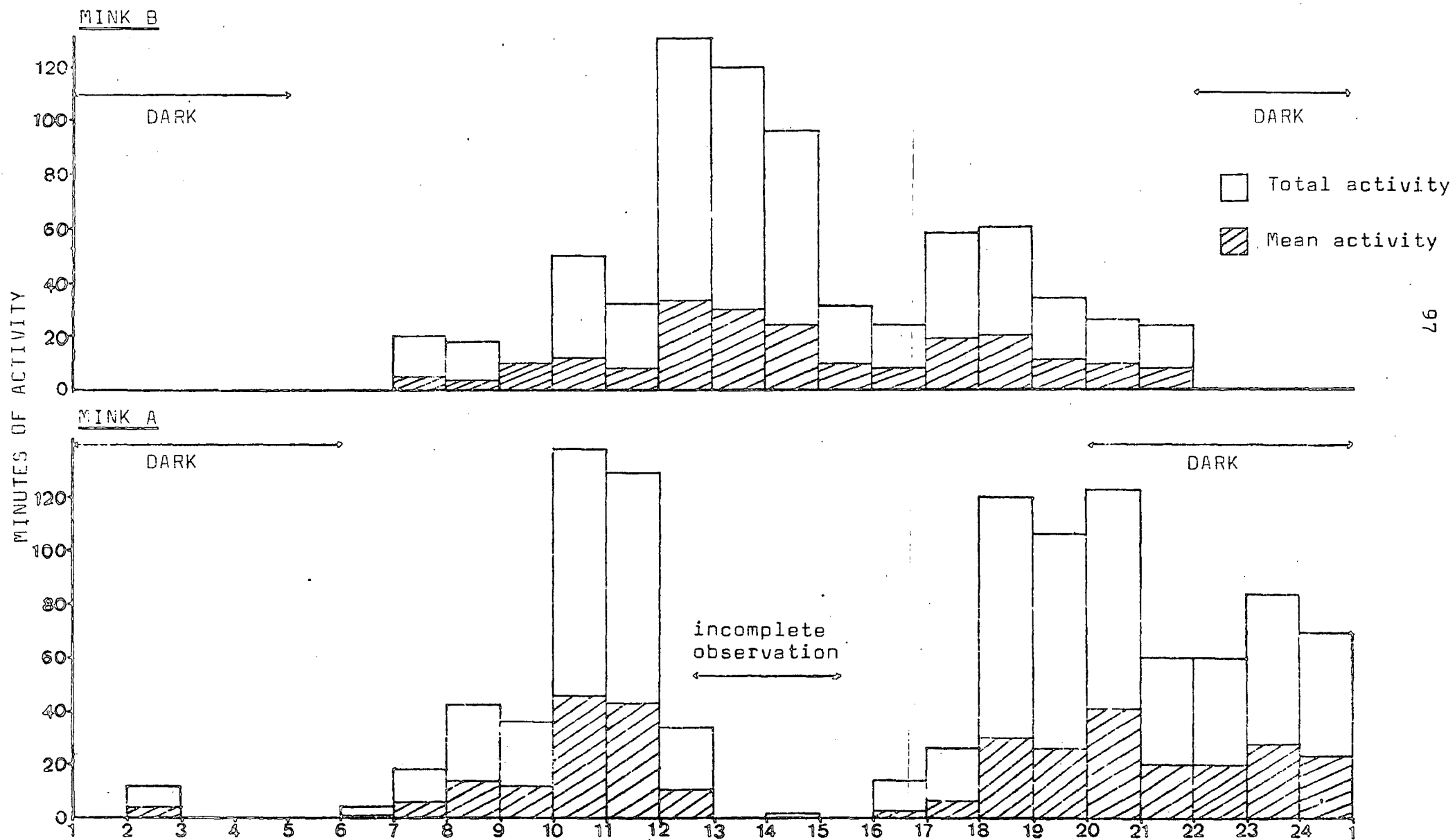
intensive activity; Mink B between 1 pm and 3 pm and from
5 pm to 7 pm. Mink A's activity peaks were slightly different,
being 10 am to 12 pm and 6 pm to 9 pm with a fairly high
sustained level of activity from 9 pm to 1 am. Mink A was
tracked during April, the end of the breeding season when
males are normally very active.

MOVEMENT

Only the results obtained from tracking Mink B will
be discussed. The longest distance travelled during a single
bout of activity was 470 m which was covered during a period
of seven hours. Contact was lost during this period however,
so the exact extent of the journey was unknown. The mean
speed was calculated from all those journeys of which the
starting and finishing time were known accurately, and was
2.7 m/min. The fastest travel time was recorded when the
mink moved 244.6 m in 57 min, giving a mean speed of
4.3 m/min.

In the field the activity pattern seemed to be
based on a period during the morning when movement was
concentrated around the den site used during the previous
night. Around noon, after a short lull, rapid activity was
often registered as the mink covered considerable distances
along the river bank during periods of continuous movement;
it was at this time that most of the day's travelling
occurred. Activity invariably decreased again during late
afternoon prior to a mid-evening bout which was similar to
that of the morning in that activity was concentrated in
a single area.

The animal was visible for much of the time that

it was travelling (60-70%), and seemed to prefer a path along
the water's edge, hopping between boulders and running along
the muddy shore. After each brief period in the water, the
animal shook itself dry. On several occasions it was seen
to dive and remained submerged for an average of four
seconds. Both mink A and B remained within 10 m of the river
during the tracking period.

During the study, mink B used a different den
site each night, however, three of these were within 135 m
of each other. The first night was spent under a pile of
brushwood and fallen trees several metres from the release
point (trap 2 on Fig 16). The second night was spent 470 m
upstream on the "Island". The final two nights were spent
close to the original trap site, and during this period,
all activity was restricted to a 309 m length of the river.

PRESENCE OF OTHER MINK

Prior to mink A's capture, an adult female was
caught in trap 3 (Fig 16), but subsequently died as a
result of mating and trapping injuries. During the April
tracking period, two mink were heard screaming and fighting
and it is possible that mink A was one of them.

During the four days in August, three mink other
than mink B were also seen. A chocolate coloured mink,
possibly female (mink C) was observed on August 22 near a small
feeder stream (point A, Fig 16) close to mink B's last
known position at that time. The following day she was
sighted further downstream near trap 2 and was observed
attempting to catch a moorhen. The second animal, (mink D)
had a dark brown pelage and was smaller than mink B (and
thus possibly a female). On two consecutive days this

animal chased mink B out of a clump of sycamore trees, accompanied by much vocalisation, causing mink B to move upstream.

The third animal, mink E, was another Silver-Blue, possibly adult. It appeared from the rushes and came 20 m up the bank passing very close to the observer before entering a den in a dead tree. On emerging several minutes later, it continued downstream, sniffing as though following a trail. On later inspection, the den was found to contain three rabbit carcasses and numerous bird remains. It is possible that it was a breeding den and thus that mink B, C and E were related.

DIET

During the course of the tracking period, mink B was known to have attacked and consumed a rook with a damaged wing. At one point, he was seen to emerge from the river with a fish in his jaws, possibly a minnow. Six hours after his release, he was seen to eat two laboratory mice which been left near the trap site, and whilst in captivity had consumed four one day old chicks. Mink A was observed to catch a juvenile rabbit. Both mink A and B were observed eating vegetation, and both seemed to preface a bout of activity with a drink from the river.

DISCUSSION OF RADIO-TRACKING RESULTS

During the course of the tracking period, it became abundantly clear that the number of scats present does not give an accurate indication of the number of animals present. Chanin (1976) and Wise (1978) have taken

changes in the number of scats found to be an indication of
mink activity, however, this must be viewed with caution and
related to the conditions for scat collection, for example,
heavy rain is likely to remove scats. Neither are tracks
a very reliable indication, as a single mink may cover a
large area of river bank in a relatively short time and has
been known to track back and forth repeatedly along mud banks
producing a number of tracks. As the pad marks of an individual
can only be recognised when the ground consistency is
favourable and then usually only by an experienced tracker,
this can be a very inaccurate method of assessing population
size. This must certainly be borne in mind when considering
the results of surveys on the rivers Blyth, Wansbeck and
Font. Mink have been reported on the river Blyth (Watson,
pers. comm. and Richardson, pers. comm.), but no signs of
their presence were found.

The most striking result from this study was
perhaps, the diurnal nature of mink B's activity pattern.
Both Gerell (1969) and Birks (pers. comm.) have reported a
mainly nocturnal pattern in the mink which they have
tracked, the only exception being a female which became
diurnal in the lactation phase. It is possible that mink B,
being a juvenile, was still affected by the same factors
which prompted Gerell's (1969) female to become diurnal.
During the present study, three other animals were also
seen during the day and much of mink A's activity occurred
during daylight hours. The results from tracking mink A
may, however, be unrepresentative as the animal died a few
days after the tracking period from an apparent malfunction
of the liver, either due to trap stress or as a result of
mating stress. Mink A's activity apparently increased just

prior to dusk and decreased towards midnight. From
Corbet and Southern's (1977) general account of mammals it
appears that the majority of the minks' prey species are
either crepuscular or nocturnal.

Apart from the timing of activity, the movements
involved also bear some scrutiny. During the early and late
bouts of activity mink B remained close to a den site,
almost as though foraging within a restricted area. At
midday, however, the pattern became very different, large
distances were covered at high speed with virtually no
interuption, it was at this point that much of the tracking
back and forth was apparent. An oscillatory pattern
similar to that described by Gerell (1969) was noted. On day
two, mink B travelled to the "Island" and once there
travelled back and forth in a restricted area prior to
moving back to trap 2 on day three. After a brief foray
upstream in the morning of day four, he travelled downstream
to trap 3 and then back to spend the night at den 5 (Fig 16).
On day five, he travelled down to the sycamore trees
and oscillated between the trees and an area 200 m further
upstream before returning to trap 2.

Gerell (1969) and Chanin (1976) noted that the
kits normally remain with the mother until July/August and
it is possible that by late August mink B was either
attempting to establish a territory or familiarizing
himself with the maternal territory prior to dispersion.
This speculation is based on the fact that two other mink
were seen within a small area in which mink B spent much of
his time, yet no signs of aggressive interaction were
observed, thus they may have been siblings, whilst further

downstream mink B was chased off on two occasions by mink D.

The use of a different den site each night is in
accord with Schladweiler and Storm's (1969) results and
may possibly be governed by the availability of shelter
close to a "kill". Nights 1,3 and 4 were spent within 150 m
of each other and it would presumably have been possible for
the mink to return to the same den each night, however,
a different one was occupied on each occasion. On day four,
mink B was found to have killed an injured rook which had
been frequently observed in the area. The carcass was
found in a den known to have been occupied by mink B in
close proximity to the rook's last known position. Thus it
seems likely that, having made a "kill", the mink simply
repairs to the closest available shelter. Thus a habitat
providing a large number of potential den sites is likely to
be favoured; Gerell (1969) and Errington (1946) both note
that lack of den sites may restrict mink colonisation.

APPENDIX 2 :   DETERMINATION OF CONVERSION FACTOR FOR CRAB

REMAINS

METHOD

      Two mink were deprived of food for 24 hours prior to the feeding trial, to ensure complete evacuation of the gut. Each mink was given an excess of shore crab, C.maenas, total weight, 185 g. A control weight of crab was placed near the cages during the experiment to ascertain the percentage water loss. The prey remains were removed from the cages the following morning and the scats were collected. The scats were dried at 50°C for 24 hours prior to weighing.

      Having taken into account the percentage water loss of the control remains, the amount of crab consumed was calculated and was divided by the weight of scats produced, to calculate a conversion factor.

RESULTS

%water loss of control = $\dfrac{\text{weight loss due to evaporation}}{\text{initial weight of crab}}$ X 100

$$= \frac{1.73}{19.79} \times 100 = 8.7\%$$

Wt. of uneaten hydrated crab remains =

A) $25.34 + \left(\dfrac{8.7 \times 25.34}{100} \right)$ B) $55.73 + \left(\dfrac{8.7 \times 55.73}{100} \right)$

                =27.75 g   =61.04 g

Wt. crab presented =   182.24   189.02

Wt. crab remains   = - 27.75   - 61.04

Wt. crab consumed =   154.49   127.98

Wt. scats produced =   12.79   6.12

C.F. = $\dfrac{\text{Wt. ingested}}{\text{Wt. scats}}$ = $\dfrac{154.49}{12.79}$ $\dfrac{127.98}{6.12}$

                          =   12.08   20.91

$$\text{Mean C.F} = \frac{154.49 + 127.98}{12.08 + 6.12} = \frac{282.47}{18.2}$$

$$= 15.5$$

DISCUSSION

The estimation of a correction factor based on a single feeding trial using only two animals must be viewed with scepticism but is included here for completeness. In this case, the individual mink were observed to use different feeding strategies and this may have either increased the inaccuracy of the method or may have mimicked the situation in the wild. Until there are observations of wild mink feeding on crabs, the efficacy of the method cannot be assessed. The same reservations must, however, apply to previous estimates of Conversion Factors for various prey types (e.g. Wise, 1978).

One of the two animals ate the crabs complete, crunching the carapace, whilst the other attempted to kill the crab with a bite in the carapace and then removed the carapace and ate only the contents.

APPENDIX 3   CHARACTISTIC VERTEBRAE
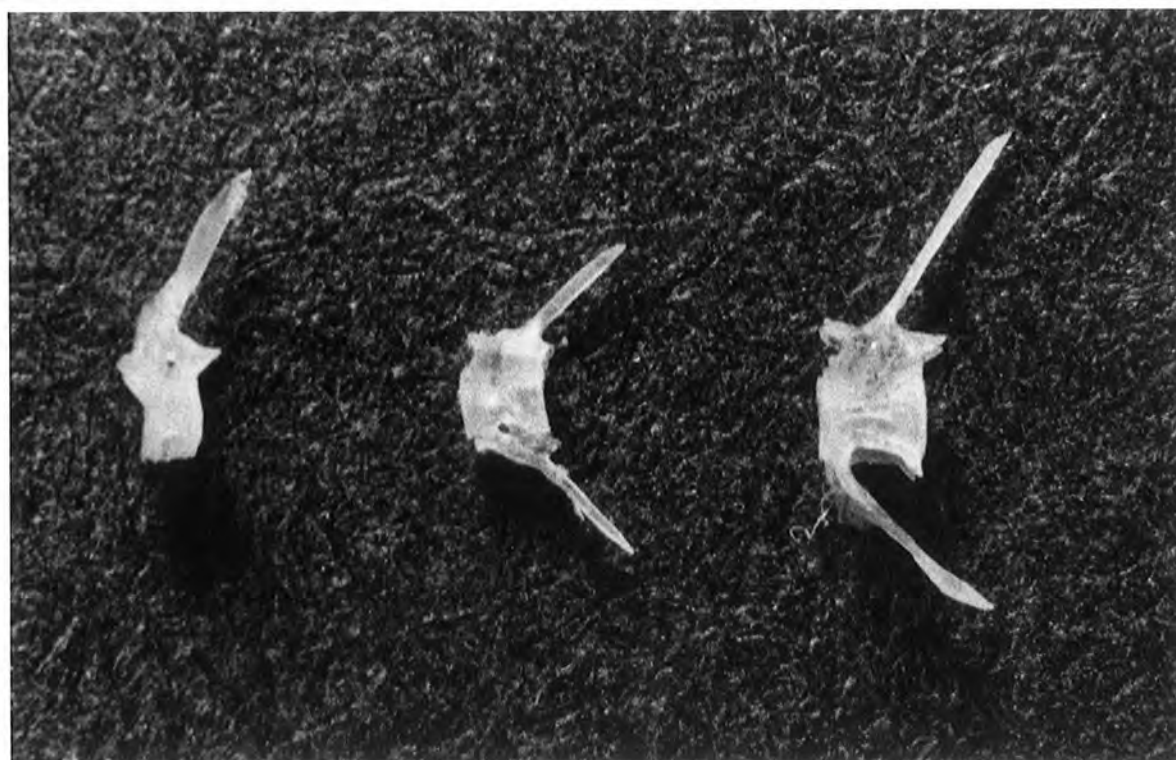
VERTEBRAE FROM THE COMMON BLENNY

Anterior abdominal to posterior caudal vertebrae, from left to right.
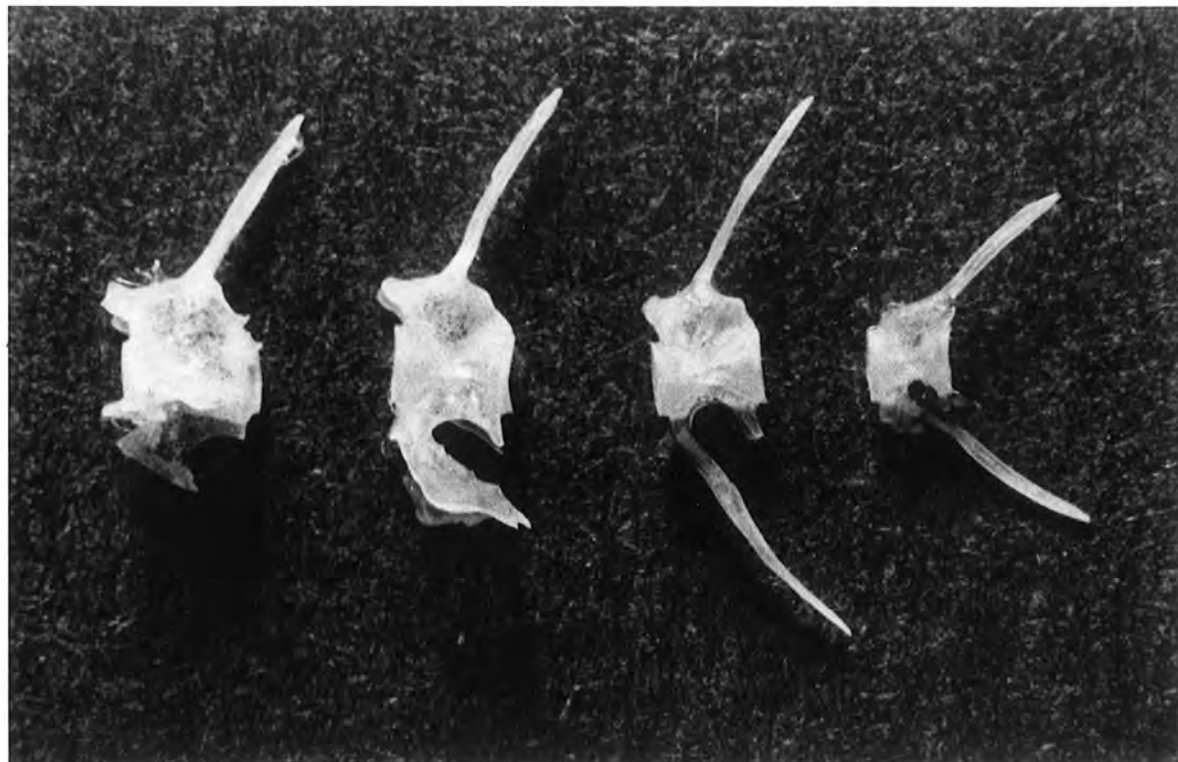
VERTEBRAE FROM THE BUTTERFISH

Anterior abdominal to caudal vertebrae, from left to right.

Photographs from P.Wheeler.

SUMMARY

1. Mink scats were collected from two riparian areas in Northumberland and a coastal site in Galloway, in order to investigate the spring and summer diet of feral mink.

2. The order of importance of the major prey groups in the riparian habitat was:- mammal, fish, bird, amphibian.

3. There was seasonal variation between spring and summer, as the diet changed from a predominance of fish to one of mammal, with a decrease in the importance of amphibians.

4. On the coast, the main prey groups in order of importance were:- fish, crab, mammal and bird.

5. There was temporal variation in the coastal diet over the three collection periods in June and July, the mammal group becoming increasingly important.

6. Half the riparian diet was composed of terrestrial species, with aquatic and semi-aquatic species providing the remaining two quarters respectively. On the coast, the three types were equally represented.

7. As few scats were collected initially, an individual was trapped and radio-tracked in an attempt to ascertain how much time mink spent close to the water course.

8. The juvenile male tracked exhibited a diurnal activity pattern, remaining within 20 m of the river, and displaying much exploratory behaviour.

9. It was concluded that mink and otter did not compete during spring and summer in the riparian habitat and that they would be unlikely to do so on the coast were they sympatric.

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